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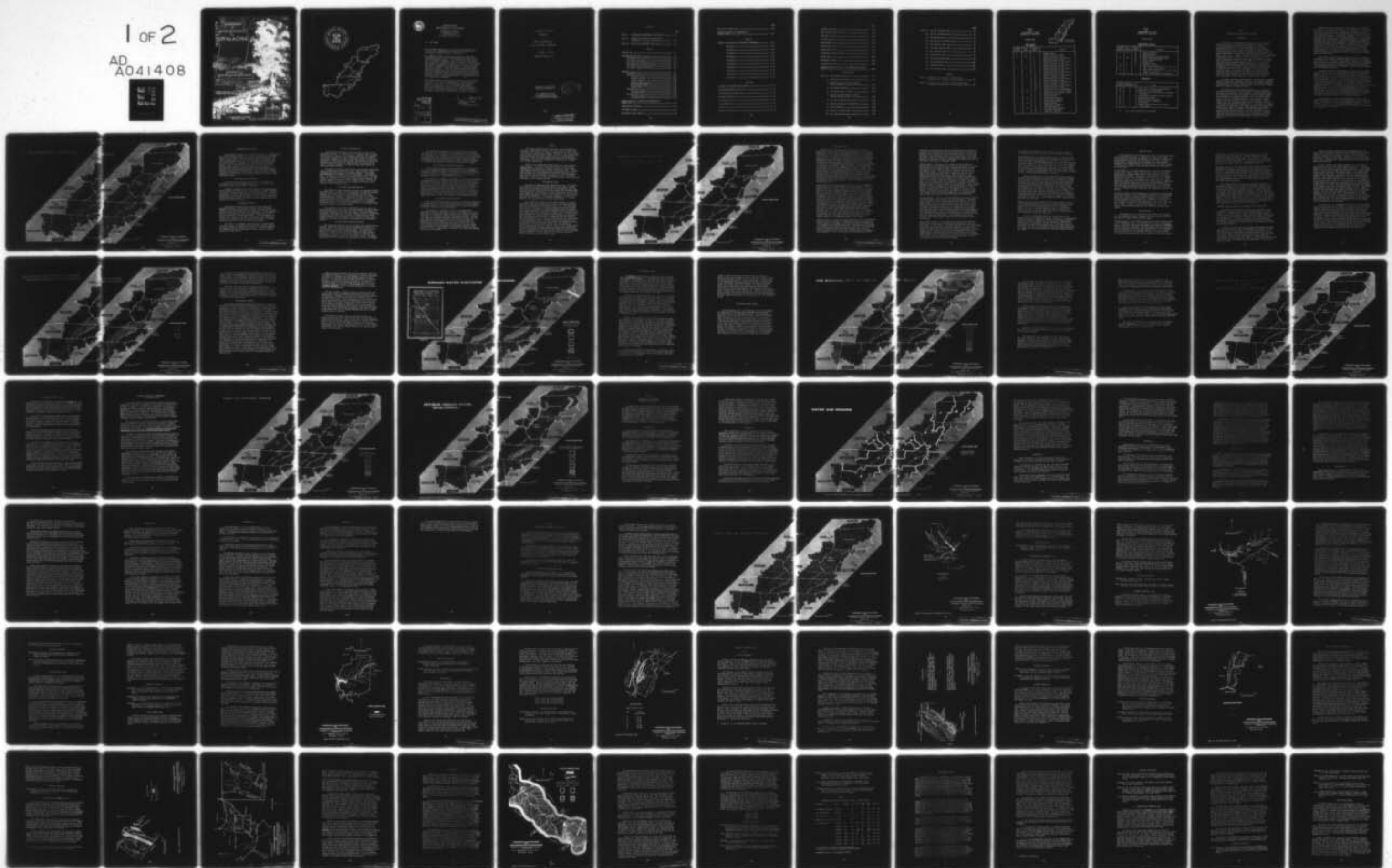

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Development of WATER RESOURCES in APPALACHIA

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APPENDIX H.

GROUND WATER RESOURCES.

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GEOLOGICAL SURVEY

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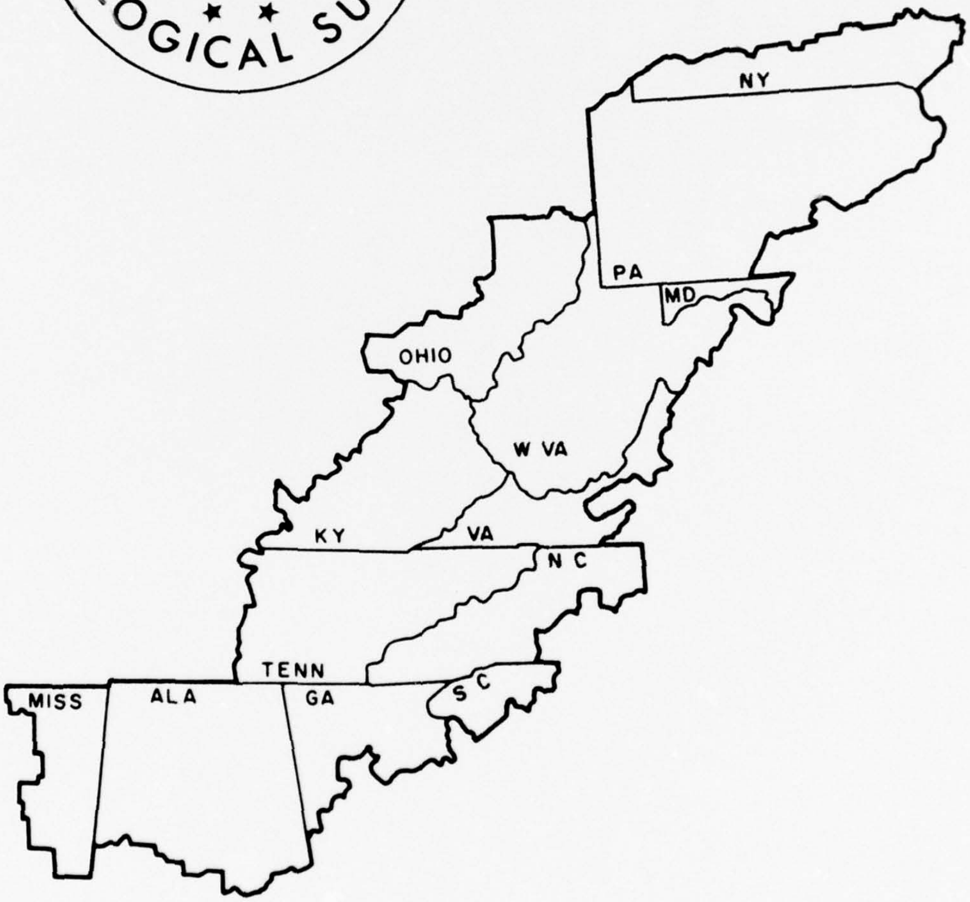

UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
317 Washington Building
Arlington Towers
Arlington, Virginia 22209

TO: THE READER

This Appendix, designated as "H" and entitled "Ground Water", is one of the 9 Appendices that support the "Report for Development of Water Resources in Appalachia."

This ~~Appendix~~ document provides figures on the amount of available ground water and the costs of developing ground-water supplies for broad planning purposes. It is divided into three parts. Part I describes, in general terms, the relative availability and occurrence of ground water and the relative cost and optimum development of ground-water supplies for the Region as a whole. Part II is a summary, by Water Sub-Region, of the generalized information in Part I. Part III presents ground-water information at specific sites which have been selected for study by the Corps of Engineers because of obvious needs for local water supplies to stimulate local economic growth. The Appendix was prepared by the U. S. Geological Survey in cooperation with the U. S. Army Corps of Engineers.

This Appendix supports the main report which is also organized into Parts. Part I is the Summary Report, which should be consulted for an overall view of the Appalachian Region. Part II is comprised of parts of chapters providing more definitive information on each of the 10 Water Sub-regions. A full index of the report components is included at the end of the Table of Contents for this Appendix on pages VI and VII.

Granville G. Wyrick
Hydrologist
U. S. Geological Survey

GROUND-WATER RESOURCES

APPENDIX H

To

REPORT FOR DEVELOPMENT
of
WATER RESOURCES IN APPALACHIA

By

Granville G. Wyrick
and
Orville B. Lloyd, Jr.

Prepared by and Printed
under the Direction of

U. S. GEOLOGICAL SURVEY
in cooperation with the
U. S. ARMY CORPS OF ENGINEERS

1968

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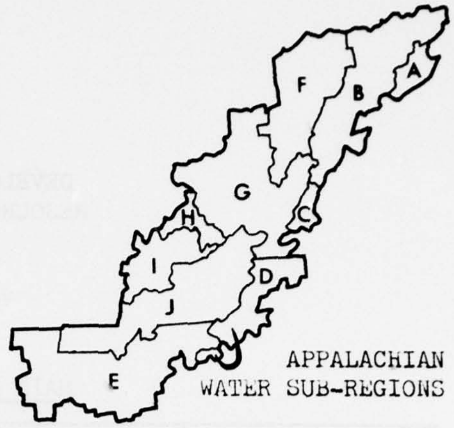

APPALACHIAN
WATER SUB-REGIONS

MAIN REPORT

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REPORT
For
DEVELOPMENT FOR WATER
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VOLUME INDEX

PART I

GROUND-WATER RESOURCES OF THE REGION

INTRODUCTION

The study of the ground-water resources of the Appalachian Region, from which this report was prepared, was made by the U. S. Geological Survey in cooperation with the Office of Appalachian Studies, U. S. Corps of Engineers. The report is divided into three parts. Part I describes, in general terms, the occurrence and availability of ground water and the cost and optimum development of ground-water supplies for the Region as a whole. Part II is a summary, by water sub-region, of the generalized information in Part I. Parts I and II are intended for use in broad area planning and are not intended to give specific ground-water information at specific sites. Parts I and II, considered with other water resources reports, will provide a basis for planning the development of water resources as a stimulus for economic growth in the Region. Part III presents ground-water information at specific sites which have been selected because of obvious needs for local water supplies to stimulate local economic growth. Information from Part III, considered with other water resource reports, may indicate the most economical sources of water supplies for local economic growth which, in turn, may benefit the economy of the Region and the Nation.

The cost estimates presented herein are based upon stipulated general assumptions. Although essential to and valid for planning activities where different sources of water are compared broadly, they should not be used for detailed local planning unless supplemented by competent professional advice.

The importance of ground-water supplies as a catalyst to economic growth should not be overlooked in the water resources planning for Appalachia. This statement is based primarily upon the promptness with which ground water can be developed in whatever quantities are locally available. In a few places ground water is the most economical source of water supply. In many others, where the ultimate economy of a surface-water supply is greater, the fact that ground water can be developed in two or three months and generally near the point of use makes it possible to provide the industrial or municipal supplies that would quickly enhance the economy of an area. Under favorable circumstances such supplies would be adequate to sustain the needs of the economy until more ample sources could be developed, a process which may well require several years. The wise use of limited supplies of ground water may thus hasten the development of an area that will ultimately require larger supplies from other sources.

Detailed studies of sources of water supplies by population are scarce in the Appalachian Region. In a few parts of the Region such studies have been made. One study, conducted by the North Carolina State Board of Water Commissioners in 1956, indicated that in the Appalachian part of that state, in seven counties the entire population relies on ground-water supplies, in 20 of the counties more than 50 percent of the population relies on ground-water supplies, and in two counties less than 50 percent of the population relies on ground-water supplies. The higher percentages of population dependent upon ground-water sources seems to be related to the lack of urbanization. In each of the two counties where less than 50 percent of the population relies on ground-water supplies, there are municipalities serving populations of more than 100,000. In the seven counties where all of the population relies on ground water supplies, there is no municipality serving more than 2,000 people.

While these figures apply to only one part of one state, it is probable that a similar situation exists in most of the Region and in the area to the west of the Region. However, this situation does not exist in the southern part of and to the east of the Region, where the highly productive aquifers of the Coastal Plain allow the extensive development of ground-water sources for large municipal and industrial supplies.

The author wishes to acknowledge the cooperation and assistance of Col. John C. H. Lee, Jr., Director, Office of Appalachian Studies, and his staff, in developing the study of the ground-water resources. Mrs. Jo Doris DiAngelo, of the Geological Survey Office in Cincinnati made most of the thousands of computations used in the preparation of Parts I and II and Mrs. Virginia Tharp made most of the computations in Part III. The State Geological Surveys and State Water Resources Agencies in the Region provided much valuable information. Authorship for selected site reports in Part III different from that authorship of the main report is shown for each such study. The 13 U. S. Geological Survey Districts including parts of the Region furnished reports and basic and interpretive data collected during cooperative State-Federal programs. The study was made under the direct supervision of Mr. Henry C. Barksdale, Staff Hydrologist, U. S. Geological Survey.

The Appalachian Region, as designated by the Appalachian Regional Development Act of 1965 and amendments, includes all, or parts of 13 States and seven physiographic provinces, as shown on the map in Figure 1. The varying occurrence, availability and cost of producing ground-water supplies are described in the following sections of this report.

PHYSIOGRAPHIC PROVINCES

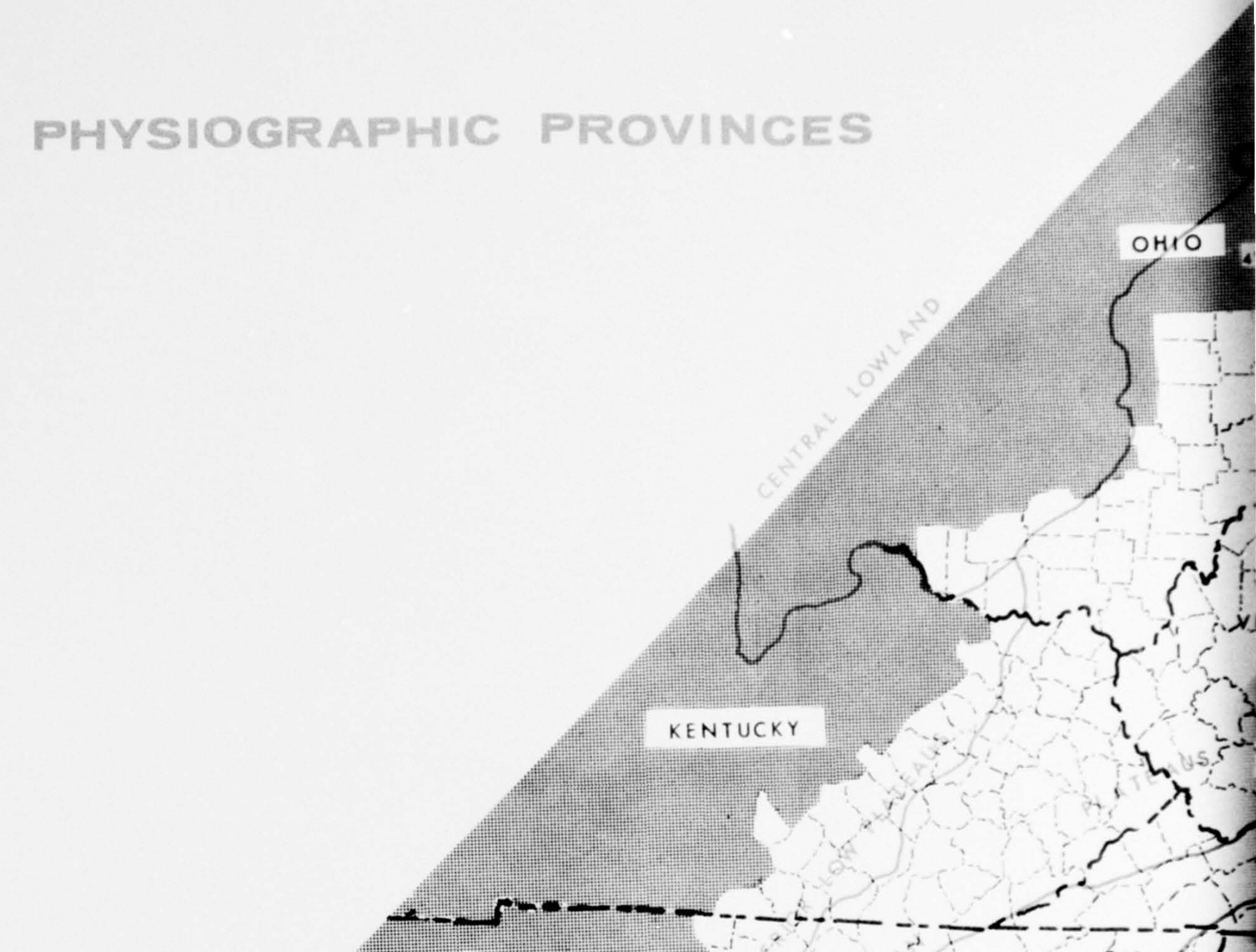
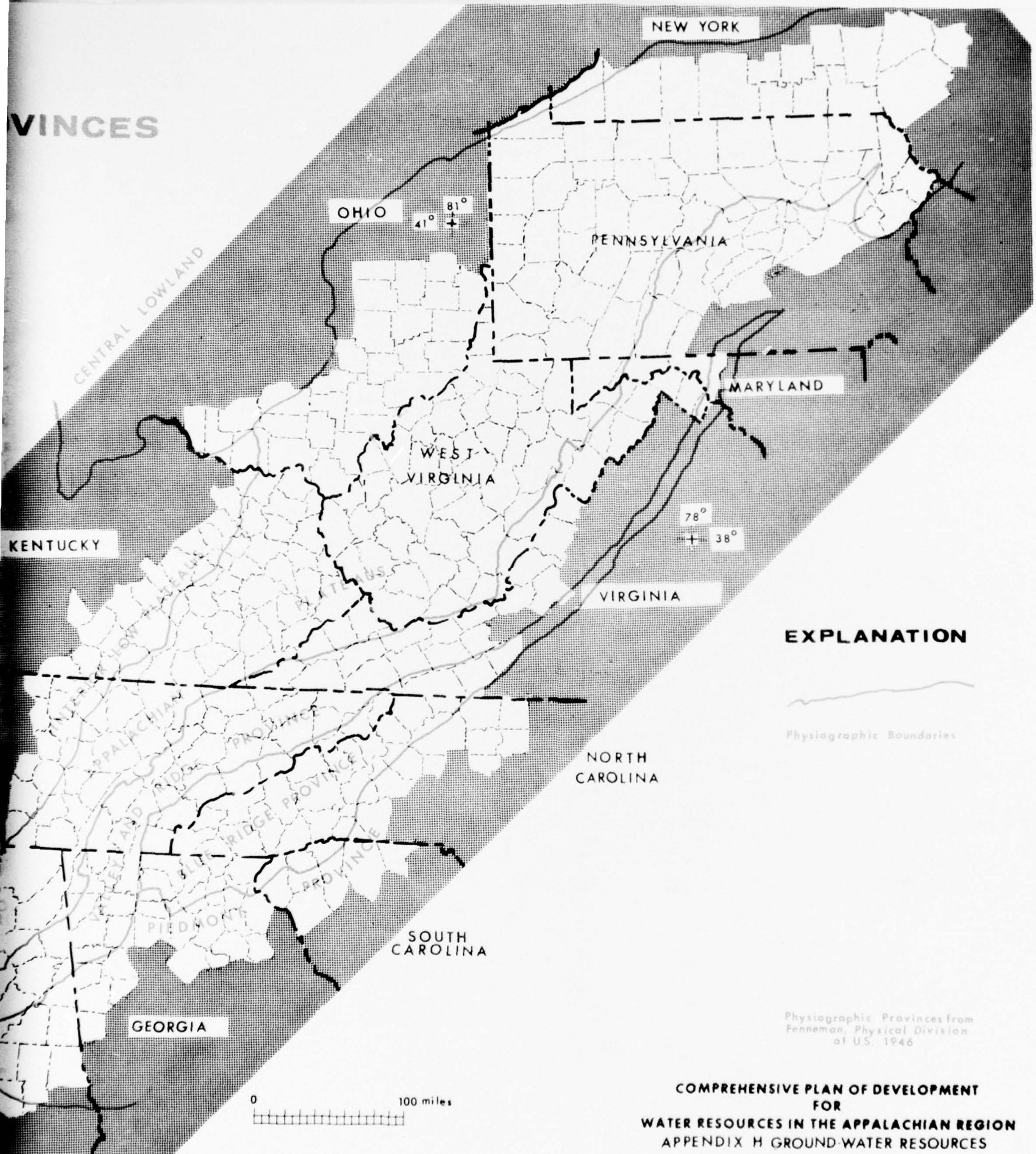


Figure 1.- Physiographic provinces of the Appalachian Region

VINCES



EXPLANATION

Physiographic Boundaries

Physiographic Provinces from Fenneman, Physical Division of U.S. 1946

COMPREHENSIVE PLAN OF DEVELOPMENT
FOR
WATER RESOURCES IN THE APPALACHIAN REGION
APPENDIX H GROUND-WATER RESOURCES
prepared by
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Geological Survey

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PHYSIOGRAPHIC PROVINCES

The Appalachian Region, now commonly referred to as "Appalachia", is a region legally defined on the basis of economic and political divisions and includes more than one physiographic province. The Region includes parts of three major physiographic divisions and seven physiographic provinces. The three major divisions include the Atlantic Plain, the Appalachian Highlands and the Interior Plains. These major divisions are divided into provinces. The Atlantic Plain includes the Coastal Plain province, and the Interior Plains division includes the Interior Low Plateaus province and the Central Lowland province. The Appalachian Highland includes the remainder of the provinces named in Figure 1. Highly generalized descriptions of the various provinces are given in the following section.

The Coastal Plain Province

The Coastal Plain province occurs only in the south and southwestern parts of the Appalachian Region. It extends to the east of the Region from Georgia to New York.

Geologic formations of the Coastal Plain province range from Recent through Cretaceous in age. The material of these formations is generally unconsolidated beds and lenticular deposits of gravel, sand, clay, and shell. Land surface is generally flat or gently sloping with remnant beach or stream terraces. The land surface of the Coastal Plain province is formed from ocean bottom which has emerged since Cretaceous time.

The Piedmont Province

The Piedmont province occurs along the east edge of the Appalachian Region. This province includes parts of Alabama, Georgia, South Carolina and North Carolina. The eastern or outer boundary is along the Fall Line and the western or inner boundary is along the Blue Ridge and Valley and Ridge provinces. The Fall Line is considered to be the intersection of two peneplains, one formed by the surface of the older crystalline rocks underlying coastal plain sediments and the other by the plateau of the non-mountainous section east of the Blue Ridge province.

The rocks in the Piedmont province range from Precambrian to Recent in age. In general, they are granite, gneiss, schist, and slate covered by a mantle of saprolite. The land surface of the Piedmont province is generally a rolling surface of gentle slopes and slight relief.

The Blue Ridge Province

The Blue Ridge province occurs along the east edge of the Appalachian Region. It includes parts of Georgia, South Carolina, North Carolina, Virginia, West Virginia, Maryland, and Tennessee. The province is separated from the Piedmont province throughout most of the boundary by a single major fault scarp, the Blue Ridge Escarpment. Along the western boundary the Blue Ridge province is separated from the Valley and Ridge province by the eastern extent of sediments deposited in Paleozoic seas which covered the Valley and Ridge province.

The rocks of the Blue Ridge province are generally crystalline rocks of Precambrian and Paleozoic age. They have been highly metamorphosed and distorted by structural uplift. The province was peneplained and uplifted above the peneplains to the east and west. It contains the highest elevations of the Region. The land surface is irregular, with steep mountains and deep valleys. The mountain ridges are resistant rocks, uplifted about 2,500 feet above the Piedmont peneplain, and the valleys are formed by the erosion of less resistant rocks.

The Valley and Ridge Province

The Valley and Ridge province traverses the Appalachian Region from southwest to northeast and includes parts of Alabama, Georgia, Kentucky, Tennessee, Virginia, West Virginia, Maryland, and Pennsylvania. The province is bounded on the east by the Blue Ridge and Piedmont provinces, previously described, and on the west by the Appalachian Plateaus province. The province is generally bounded on the west by an escarpment separating the essentially flat-lying rocks of the Appalachian Plateaus from the highly folded rocks of the Valley and Ridge province.

The province is underlain by Paleozoic rocks that may be as much as 40,000 feet thick. The rocks are generally of marine origin and include limestone, sandstone, and shale. After deposition in a Paleozoic geosyncline the rocks were folded, uplifted, peneplained, re-uplifted, and dissected by erosion. The land form has broad valleys resulting from weathering of less resistant rocks, such as limestone, and sharp ridges where more resistant rocks withstood erosion.

The Appalachian Plateaus Province

The Appalachian Plateaus province extends from central Alabama northeast through the central part of the Appalachian Region to lower New York. The province includes parts of all States in the Region except the Carolinas and Mississippi. The Appalachian Plateaus is bounded on the east by the Valley and Ridge province and extends to the west to the Central Lowland and Interior Low Plateaus Physiographic provinces. The western boundary is roughly defined by the western extent of Pennsylvanian rocks in the Region.

The province is underlain by massive flat-lying sandstone and shale units of Pennsylvanian and Mississippian age and shale and carbonate rocks of Devonian age. In places, coal and limestone are interbedded with the sandstone and shale units. The essentially flat-lying rocks were uplifted and dissected by drainage along structurally weak joint or fault lines. The resulting topography is generally characterized by flattop ridges and deep valleys.

The Interior Low Plateaus Province

The Interior Low Plateaus province borders the southwestern part of the Appalachian Plateaus and includes parts of Alabama, Tennessee, Kentucky and Ohio. The province is bounded on the south and west by sediments of the Coastal Plain and on the north by glaciated areas of the Central Lowlands province.

The province is underlain, generally, by rocks of Mississippian and Pennsylvanian age. These rocks are primarily sandstone and shale with interbedded limestone and coal. The rocks dip generally to the north and west, away from the highland of the Appalachian Plateaus. Land surface in the Interior Low Plateaus is similar to that in the Appalachian Plateaus except that the area of the Interior Low Plateaus was not uplifted as much and, thus, the relief from dissection of the surface is not as great. The flat uplands constitute a greater percentage of the area and the stream valleys are less deep and steep than in the Appalachian Plateaus.

The Central Lowland Province

The Central Lowland province borders the Interior Low Plateaus in southwestern Ohio and the Appalachian Plateaus in Ohio, Pennsylvania, and New York. Most of the province is in the area covered by glaciers during the Quaternary Period.

The province is underlain by bedrock deposited during Ordovician, Silurian, and Devonian times. The bedrock is, for the most part, of sedimentary marine origin and is composed of shale, sandstone, and limestone in massive well-indurated beds. The bedrock units are generally flat and undistorted by folding or faulting. Bedrock is overlain throughout most of the province in Appalachia by glacial deposits. In the interstream areas the glacial deposits are mostly unsorted, clay to cobble-size till. In the stream valleys the glacial deposits have been well sorted and redeposited by stream action into stratified layers of sand, gravel, and clay. Land surface is generally flat with very moderate relief in this province.

GEOLOGY

The various characteristics of rocks, their permeability, structure, composition, thickness and extent, have a direct relationship to the occurrence, quality, availability and cost of procuring their contained ground water. Because of that relationship, this section deals with the general geology of the Appalachian Region as a basis for understanding the ground-water resources of the Region. The rocks are classified by their age of formation and by their composition.

Rocks in the Region were formed during four major geologic time divisions. The oldest rocks were formed during the Precambrian Period, more than 520 million years ago. Other rocks formed during the Paleozoic, Mesozoic and Cenozoic Eras. Calculations indicate that the Paleozoic Era occurred from 185 to 520 million years ago, the Mesozoic Era from 60 to 185 million years ago, and the Cenozoic Era from the present to about 60 million years ago. Rocks in the Region are described under these four major divisions in the following section.

Precambrian Rocks

The areas of Appalachia where Precambrian rocks are exposed are generally the most mountainous parts of the Region. These areas were not mountainous during parts of Precambrian time but, for the most part, were the bottoms of oceans where sediments were being deposited. The sediments -- sand, clay, gravel and silt -- were eroded from nearby higher land and deposited in the seas that then covered Appalachia. Through many thousands of years of deposition great thicknesses of sediment accumulated in a trough, formed by the gradual settling of the ocean bottom.

The combination of weight of overlying sediments, internal earth heat, heat from igneous activity, and rock deforming forces altered the sediments to metamorphic rocks. At a time, probably near the end of Precambrian time, the highly metamorphosed rocks were uplifted and folded by mountain building forces and exposed to erosional processes. The eroded materials formed deposits that were compacted to form sandstone, and shale units and under more intense metamorphism formed phyllite, metasiltstone, and quartzite, and eventually, gneiss and schist. Depending upon the degree of local metamorphism, units of all of these metasediments are exposed to the Appalachian Region. Locally the rocks were subjected to igneous intrusives and in rare cases dunite and pegmatites outcrop in association with Precambrian rocks. The rocks mapped as "Precambrian" in Figure 2 are those of known age and include schist, gneiss, feldspathic sandstone, phyllite, slate, and conglomerate. The rocks designated as "Precambrian and Paleozoic" include gneiss, schist, metasedimentary and igneous units that may have been formed during Precambrian time but have been considerably altered by igneous activity in early Paleozoic time.

GEOLOGY OF THE REGION

After

Geologic Map of North America, 1965

U.S. Geological Survey

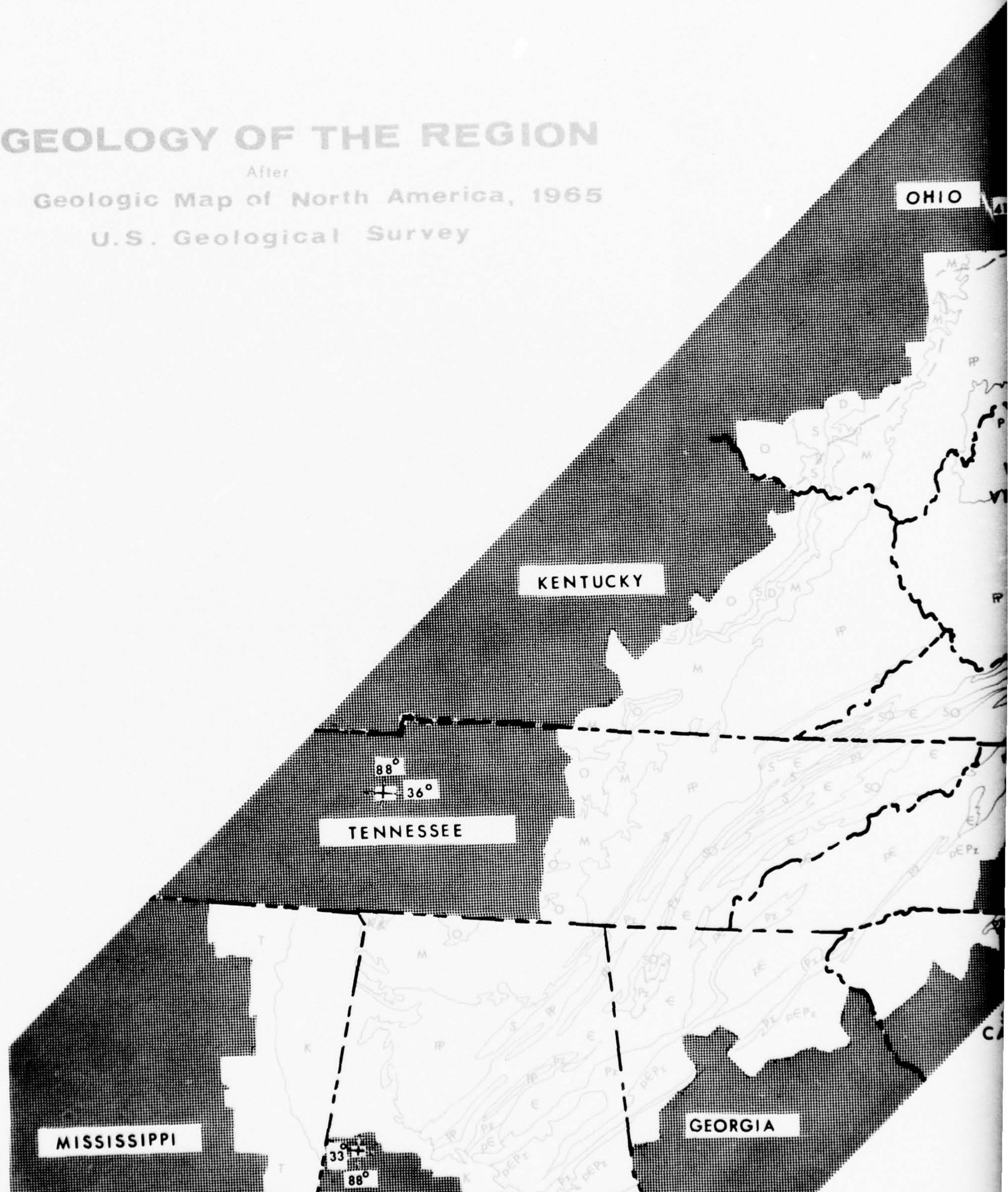
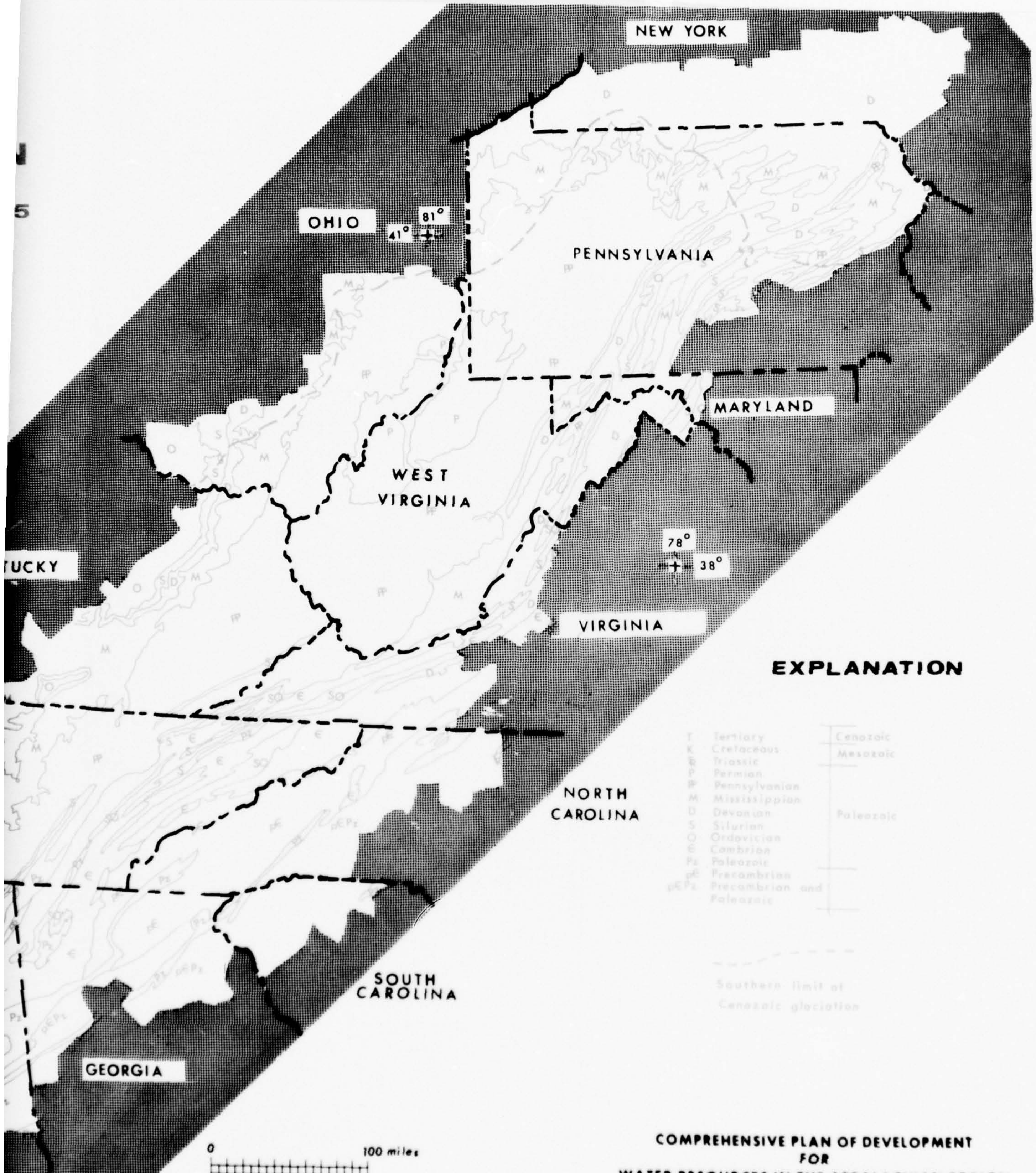


Figure 2.- Geologic Map of the Appalachian Region



EXPLANATION

T	Tertiary	Cenozoic
K	Cretaceous	Mesozoic
Ѣ	Triassic	
P	Permian	Paleozoic
IP	Pennsylvanian	
M	Mississippian	
D	Devonian	
S	Silurian	
O	Ordovician	
Є	Cambrian	
Pz	Paleozoic	
pЄ	Precambrian	
pЄPz	Precambrian and Paleozoic	

Southern limit of Cenozoic glaciation

COMPREHENSIVE PLAN OF DEVELOPMENT
FOR
WATER RESOURCES IN THE APPALACHIAN REGION
APPENDIX H GROUND-WATER RESOURCES
prepared by
U.S. Department of the Interior
Geological Survey

Paleozoic Rocks

Paleozoic rocks form the land surface for most of the Appalachian Region. These rocks lie unconformably over the older Precambrian rocks, with two main factors marking the differences in the rocks. In general, the Precambrian rocks are considerably more distorted by faulting and folding and are more highly metamorphosed than the Paleozoic rocks, and the Precambrian rocks are essentially barren of fossils in contrast to some of the highly fossiliferous Paleozoic rocks. Some of the rocks formed in the southern part of Appalachia during Paleozoic time resulted directly or indirectly from igneous activity and are not fossiliferous. These rocks are indicated as "Paleozoic" rocks on Figure 2 and include volcanic tuff, syenite, diorite, gabbro, and slate belts. The remainder of the Paleozoic rocks may be designated by the period in which they were formed because the units are either fossiliferous or, if barren, situated in stratigraphic relationship to fossiliferous units that may be dated. The rocks formed during each period of the Paleozoic Era that outcrop in the Region are indicated separately on Figure 2, and are described in the following sections.

Cambrian System -- Rocks that were deposited during the Cambrian Period extend from western Maryland to central Alabama in the Appalachian Region. These rocks were deposited under marine conditions. During the Cambrian Period the land surfaces on either side of the present Cambrian deposits were probably mountainous with an elongated depression between them. The depression was connected to open seas in the north and south and was inundated by shallow seas during most of the period. Sand, clay, silt, and gravel were eroded from the higher lands, transported by streams and deposited in the trough under marine conditions. With continuing deposition, the weight of the sediments caused the trough, or geosyncline, to sink and more sediments were deposited on the older units. Generally, the lower units were coarse sandstone and siltstone beds and the upper units were finer limestone, dolomite, and shale beds. The accumulated thickness of the Cambrian rocks is nearly 20,000 feet in some parts of the Region. The Cambrian rocks have been highly faulted and folded. Extremely resistant quartzites of Cambrian age form some of the highest ridges in the mountainous parts of the Region.

Ordovician System -- Rocks that were deposited during the Ordovician Period outcrop, generally, in narrow bands along the eastern and western edges of the Region. The Ordovician rocks were deposited in a geosyncline or numerous synclines. The Ordovician System contains highly fossiliferous limestone and shale beds which indicate that the synclinal basins were open to major seas. Distinct breaks in deposition and fossil type indicate several inundations and withdrawals of seas from the basins during Ordovician time.

In general, rocks deposited during the earlier part of Ordovician time were fine grained limestone in massive beds and the rocks deposited later in Ordovician time were coarser shale, siltstone and sandstone. The Ordovician rocks in the eastern part of the Region are highly folded and weathered, forming broad valleys where they outcrop. In the western part of the Region the Ordovician rocks are essentially flat-lying or slightly arched.

Silurian System -- Silurian rocks outcrop in the eastern and western parts of the northern section of the Region and in the central part of the southern section. Although the Silurian rocks were deposited under marine conditions they are essentially of continental origin. The high lands to the east and west of the Region were uplifted at the close of Ordovician time and were highly eroded during Silurian time. Early in Silurian time, coarse sand and gravel from the uplifted area were transported by streams to a marine basin and deposited as a conglomeratic sandstone. As the higher lands were worn down, the eroded material became finer in texture, and the sediments of the basin gradually graded to shale and limestone near the end of Silurian time. During the middle part of Silurian time iron was deposited in isolated lagoons as a hematite replacement of calcareous materials. The Silurian Period ended with a major withdrawal of the seas in the Region. The Silurian rock units, from oldest to youngest, grade from coarse, dense conglomeratic sandstone to fine grained siltstone, shale, and limestone with local deposits of hematite.

Devonian System -- The most extensive outcrops of Devonian rocks in the Region occur in Pennsylvania and New York States. Elongated bands of Devonian rocks outcrop along the northeastern and northwestern parts and in the south-central part of the Region. The rocks indicate marine deposition in the early part of the period followed by alternating marine and continental deposition toward the end of the period. Massive beds of limestone and sandstone were deposited under marine conditions early in the period when the seas were widespread. Later in the period, the seas were shallow or restricted and massive beds of both marine and continental sandstone and shale were deposited. The accumulated thickness of Devonian rocks exceeds about 14,000 feet in the northern part of the Region.

Mississippian System -- Rocks deposited during the Mississippian Period outcrop along the northeastern and southwestern parts of the Region. In the Region, rocks deposited early in the Mississippian Period are generally coarse, nonmarine sandstone and shale beds although locally there are deposits of black, fossiliferous, marine shale. During the middle part of the Mississippian Period vast thicknesses of sandstone were deposited in the Region with interbedded shale, salt and gypsum beds. In the later part of the period marine limestone and shale were deposited and overlain by thick continental beds of red shale and sandstone.

The sequences of deposition would indicate a general uplift of the Region during the latter part of the Mississippian Period.

Pennsylvanian System -- Rocks deposited during the Pennsylvanian Period outcrop over almost half of the Appalachian Region. They occur in a broad band extending from Alabama to near the New York State line in western Pennsylvania. The rocks were deposited under both continental and marine conditions in a broad syncline that, on occasions, was open to the seas but mostly was inundated by fresh water. The Pennsylvanian rocks were not highly folded, as were previously deposited units along the eastern part of the Region. In general, Pennsylvanian rocks form land surface throughout most of the Appalachian Plateaus province.

Rocks deposited early in the Pennsylvanian Period consist mainly of coarse sandstone and shale with interbedded coal layers and thin beds of limestone of both marine and fresh-water origin. The coal beds are of economic value in West Virginia, Virginia, Tennessee, and Alabama. Rocks deposited during the middle part of the period were similar in composition except that locally they contain iron ore deposits of siderite and limonite. Coal beds formed during this part of the period are of economic value in Pennsylvania, Ohio, Maryland, Kentucky, and West Virginia. The rocks formed toward the end of Pennsylvanian time consist of fresh-water limestone, shale and coal. The rocks of the Pennsylvanian Period contain most of the geologic resources of economic importance in the Region. These resources include coal, oil, gas, iron ore, and fire clay.

Permian System -- Rocks deposited in the Permian Period occur in southwestern Pennsylvania, northwestern West Virginia, and east-central Ohio. These rocks were deposited under conditions similar to those of the Pennsylvanian rocks. In general, the Permian rocks are sandstone, shale and limestone with interbedded coal beds. The rocks were deposited in a syncline under both fresh-water and marine conditions.

The end of the Permian Period was also the end of the Paleozoic Era and was marked by general uplifting of the Appalachian Region and mountain building in the present Appalachian Mountains. During the Paleozoic Era deposition occurred in a geosyncline covering most of the Region. At the end of Paleozoic time the geosyncline was uplifted and highly faulted and folded along the east edge. Erosion of the deposits of Paleozoic time started with the beginning of the Mesozoic Era and continued through the present time.

Mesozoic Rocks

Rocks deposited in the Mesozoic Era occur in very limited areas of the Appalachian Region. In general, the Region was eroded during Mesozoic times and the deposition of sediments occurred only in faulted areas and along the relatively lower edges of the uplifted lands. The Mesozoic Era is divided into three periods. Deposits of the middle period, the Jurassic, are not known to occur in the Region. Deposits formed during the other two periods are described below.

Triassic System -- The only known deposits of the Triassic Period in the Region occur in Stokes County, North Carolina. These deposits are in a buried graben that extends northeast from North Carolina into Virginia. The graben, a downthrown section between two normal faults, is an elongated, grave-like basin that formed parallel to the edge of the uplifted Blue Ridge province. Sediments were eroded from the uplifted area and deposited in the basin under continental conditions. The rocks are predominantly red sandstone with interbedded black shale and coal. Also associated with the faulting was igneous activity which resulted in the injection of basalt dikes and sills into the sedimentary rocks of the graben.

Cretaceous System -- Rocks deposited in the Cretaceous Period occur along the southwest end of the Appalachian Region. The Cretaceous Period was a time of intense erosion in most of the Region and material eroded from the uplands was deposited as continental and marine sediments along the ocean edge in the Gulf Coast area. The sediments are generally unconsolidated, thick beds of clay and sand. Toward the end of the Cretaceous Period the oceans retreated and the exposed surface of the Cretaceous sediments was eroded.

Cenozoic Rocks

The Cenozoic Era is divided into two periods, the Tertiary and the Quaternary Periods. Deposits from both periods occur in the Region in areas of limited areal extent.

Tertiary System -- Rocks deposited during the Tertiary Period occur in the southwestern part of the Region, in the Coastal Plain province. These rocks were deposited under both marine and nonmarine conditions along a shoreline. The marine and nonmarine units interfinger, indicating near-shore marine and deltaic or swamp environments of deposition. The Tertiary System of rocks in the Region includes deposits of the Paleocene, Eocene, and Miocene Epochs. The rocks are unconsolidated with the exception of limestone units.

In general, the deposits of Paleocene and Eocene times include limestone, sand, and clay beds. Locally the deposits contain glauconitic sands and lignite beds. The deposits of Miocene times are predominantly thick marine clay layers containing lenticular beds of sand and shell. The Tertiary Period ended with a general, but slight, uplift of the Appalachian Region.

Quaternary System -- Rocks deposited during Quaternary time occur throughout the Region as beach, stream, and glacial deposits. The rocks are generally unconsolidated sand, gravel, and clay deposits of continental origin although some marine beach deposits occur in the Coastal Plain province. Individually the deposits are not large enough to map at the scale used in Figure 2 but collectively the deposits are of Regional significance in that the sand beds form productive aquifers in the major stream valleys and in the Coastal Plain province.

The southern limit of glaciation on Figure 2 shows the approximate southern extent of "in place" glacial deposits, such as till. The limit is not intended to apply to glacial outwash or to alluvium deposits of glacial origin. In many places south of the limit, the glacial-alluvium deposits form thick sediments of limited areal extent in the stream valleys. In the Ohio Valley, for example, the glacial deposits were well sorted by stream action and redeposited as thick sand, silt, and clay layers in the stream valley. Beds of coarse sand, as much as 70 feet thick, overlain by clay beds occur in the Ohio Valley between West Virginia and Ohio. There, sand beds constitute major aquifers even though they are not wide enough to map at the scale of Figure 2.

GEOLOGIC FEATURES FAVORING THE OCCURRENCE OF GROUND WATER

The locations of geologic features most favorable to the occurrence of ground water in the Appalachian Region are shown on Figure 3. The three features shown - unconsolidated deposits, folded rocks and fault zones - have the most regional significance in providing highly permeable reservoirs for ground-water storage and transmission. Faulting and jointing occur in many places throughout the Region. Whenever found, they improve the chances of obtaining ground water. Only the major fault zones are indicated on the map in Figure 3.

Ground water is stored in and transmitted through the openings in the rock units. The intergranular pore space of the rocks may comprise a high percentage of the total rock volume, as in sand and gravel, and may store considerable quantities of water. If the pore spaces are well connected and not too small, the rocks will readily yield water and are said to be highly permeable. If, however, the pore spaces are small or poorly connected, the rocks will not readily yield water and the permeability of the rocks is said to be low.

Geologic processes tend to alter the permeability of the rocks. As rocks become indurated the pore spaces and their interconnections are generally reduced in size by the deposition of cementing materials in the spaces. Rocks that have not been consolidated or those that have been subjected to fracturing by tectonic forces, generally have higher permeability than unfractured well-indurated rocks.

The most significant, highly permeable rock units in the Appalachian Region are the unconsolidated sediments. Glacial deposits and the outwash of glacial material deposited in the stream valleys occur in the northern and northwestern part of the Region. Wells in these deposits, particularly those in the outwash, generally have a high yield. Individual wells in outwash deposits along the Ohio River may yield as much as 3,500 gpm (gallons per minute). These deposits generally do not store a large volume of water but they readily transmit water from streams to the wells. The outwash deposits constitute a major source of ground water in stream valleys where they have been well sorted and where they are fairly thick. The other thick, well-sorted, unconsolidated rocks in the Region are those of the Coastal Plain province. The Coastal Plain deposits range from Cretaceous to Recent in age. These deposits are interbedded sand, clay and shell units of wide areal extent. The sand units are usually well sorted and are highly permeable as are the shell units. The thickness of the sand beds range from a few feet to more than one hundred feet. Some wells tapping these units have sustained yields of more than 2,500 gpm in Mississippi. The Coastal Plain sediments contain highly productive aquifers that may be developed to economic advantage in the southern part of the Region.

Ground water may be obtained from wells in the consolidated rocks of every county of the Region. The reported yield of wells tapping consolidated rock ranges from 0.1 gpm to 2500 gpm. The highest yields in these rocks occur in association with faults, as in Carter County, Tennessee. The major fault zones trend generally northeast-southwest along the eastern part of the Region. They occur in what are probably the most highly indurated rocks of the Region. Faults shear and grind the sedimentary and metasedimentary rocks, greatly increasing the permeability of the rock units in the vicinity of the faults. The increase in the capacity of the rocks to yield water, due to faulting, is indicated in some parts of the Region by the correlation of the fault zones in Figure 3 with the areas of high well yield and areas of high ground-water discharge shown on other maps of the report.

GEOLOGIC FEATURES FAVORING GROUND-WATER OCCURRENCE

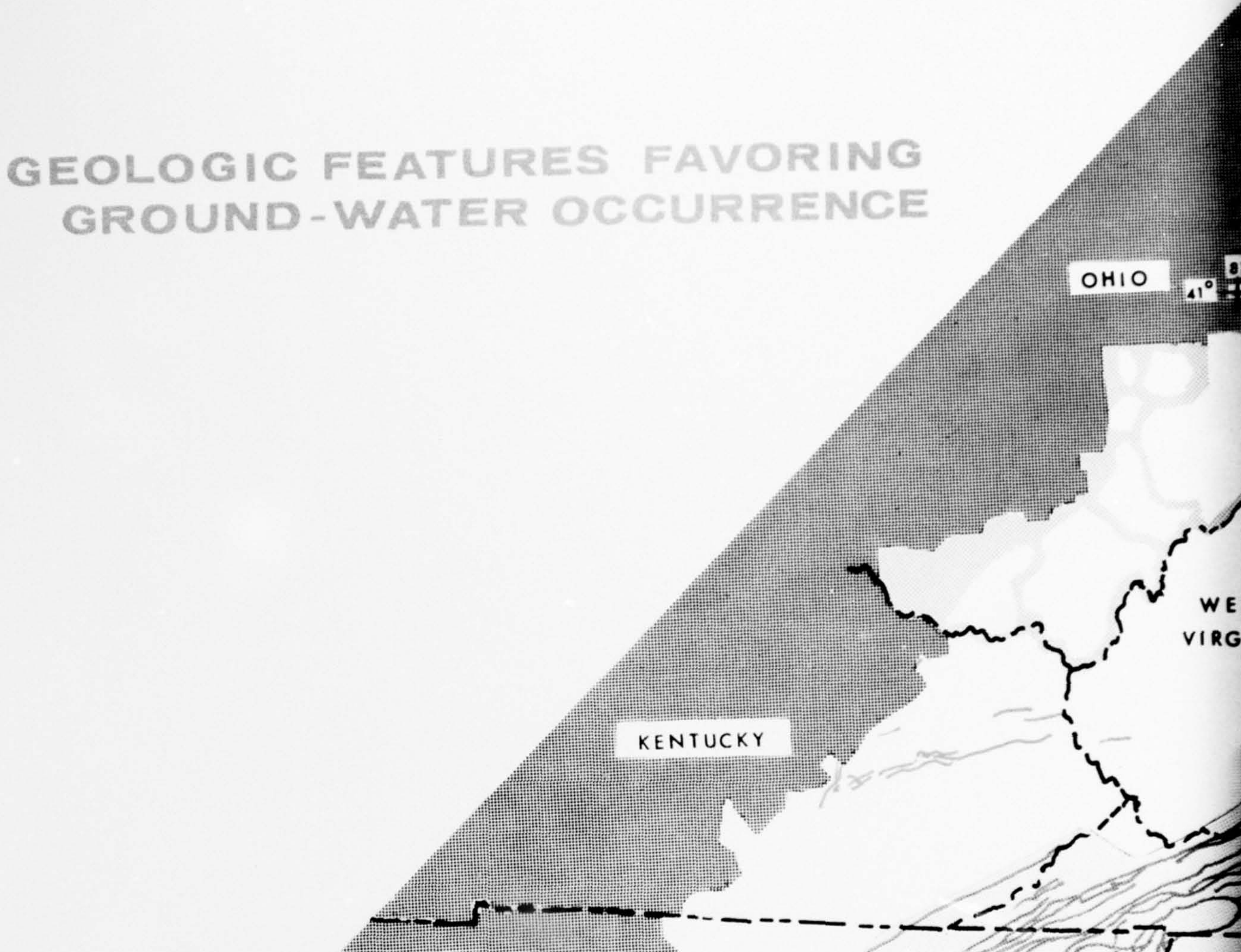


Figure 3.– Geologic Features Favoring Ground-Water Occurrence

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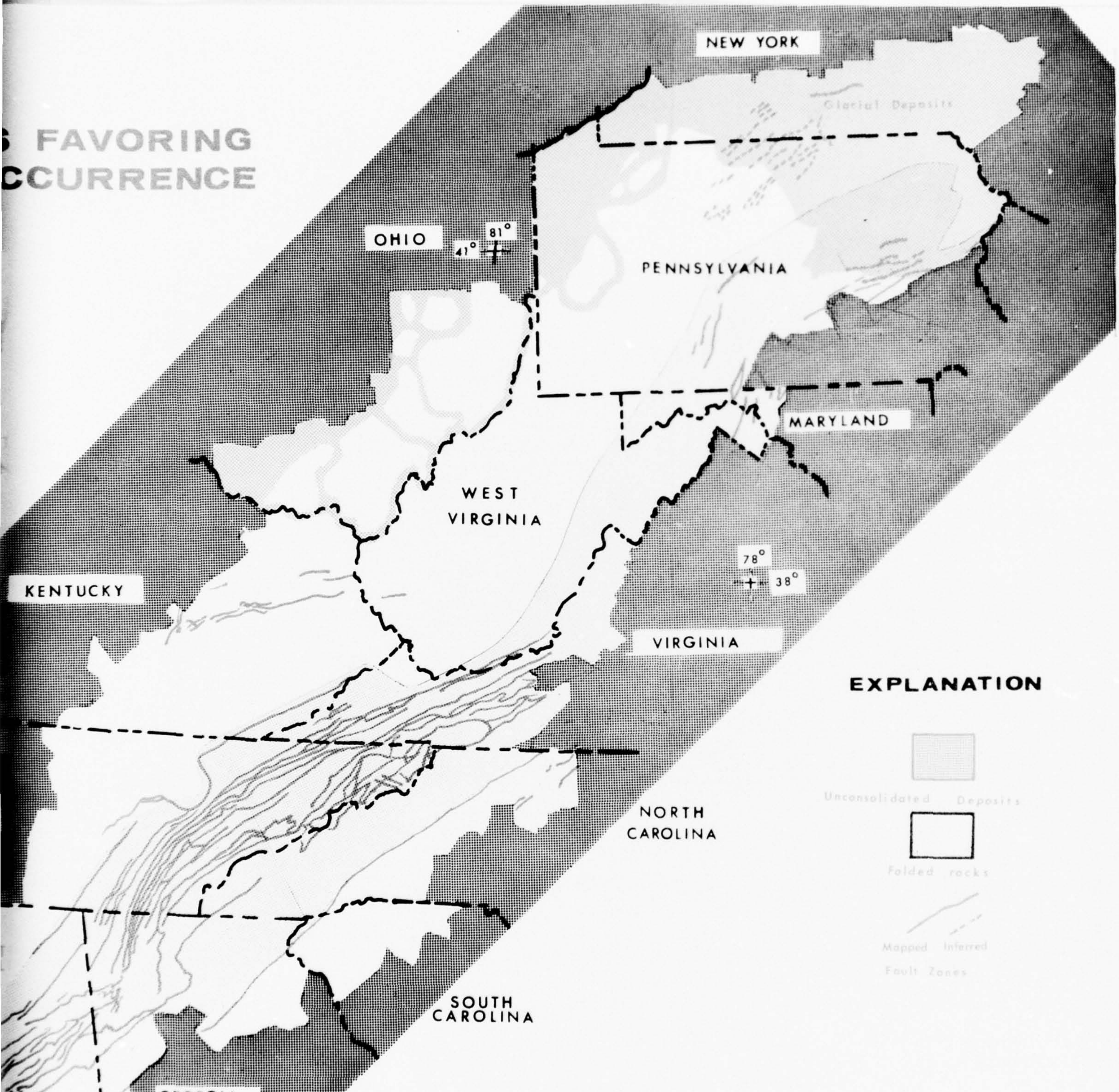

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r Occurrence

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Areas of the Region where the rocks have been folded also offer a greater ground-water potential than areas where the same types of rocks are undisturbed. Folding of strata usually results in the warping of less resistant beds and fracturing of the more resistant beds in the unit. The resulting fractures increase the capacity of the rocks to store water to some extent and greatly increase their ability to transmit ground water.

The major structural features favoring ground-water occurrence are shown in Figure 3. Locally, there are many minor faults or folds that also favor ground-water occurrence. These features are so small that they may not be mapped at this scale. Usually, these minor features may be readily observed in the field and used to advantage in the development of ground-water supplies at specific well-field sites.

GROUND-WATER DISCHARGE

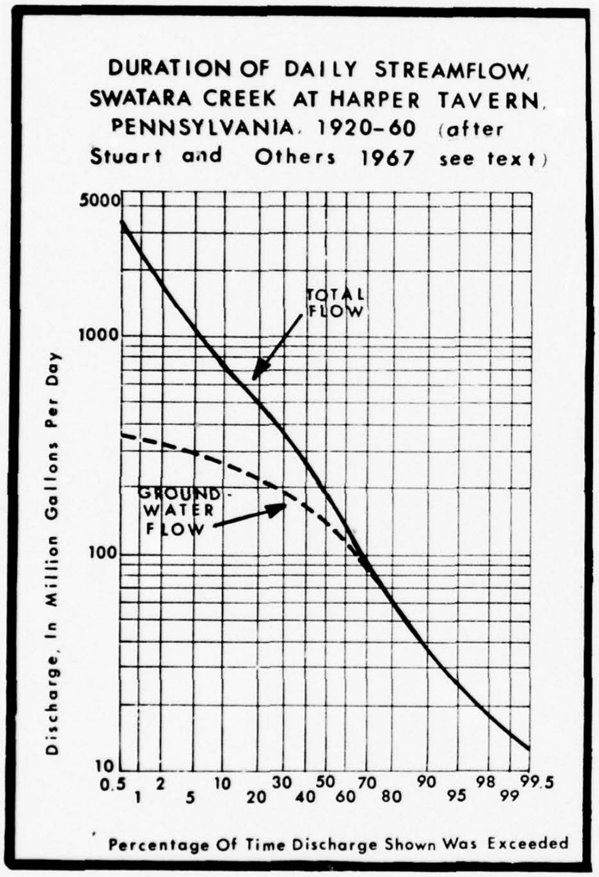
The assumed dependable ground-water discharge to streams in thousand of gallons per day per square mile of drainage area for the Region is shown on Figure 4. Ground water is constantly being discharged into the stream systems at variable rates dependent upon the permeability of the rocks and the slope of the water table. The water in streams during periods of higher flow is derived from both surface runoff and ground-water discharge. As the streamflow decreases, the water is derived to a lesser extent from runoff and to a greater extent from ground-water discharge. At the streamflow rate which is exceeded about 90 percent of the time, almost all streamflow in the Region is derived from ground water . The inset on Figure 4 is a streamflow duration curve for Swatara Creek in eastern Pennsylvania which shows both the total streamflow and the ground-water contribution to streamflow, in million gallons per day, and the percentage of time the flows were exceeded for a 40-year period of record. The curves indicated that the flow exceeded more than about 75 percent of the time is all from ground-water sources. Because detailed studies like the one on Swatara Creek have not been made for most of the Region, the generally accepted duration was used in preparing Figure 4. The low streamflow exceeding 90 percent duration has been generally accepted as the dependable ground-water contribution to streamflow. The figure was originally used in determining the base flow for the generation of firm power. Later data indicate that the ground-water yields of a basin to streamflow may range from the streamflow exceeded 60 percent of the time, in areas underlain by thick glacio-fluvial deposits, to that exceeded 90 percent of the time in areas underlain by the clayey soils of the southern Piedmont or glacial till.

Since no single duration point on the streamflow curves for the Appalachian Region can be considered as uniformly applicable, the amount of streamflow that was exceeded between 90 and 95 percent of the time was used somewhat arbitrarily in preparing this map. In preparing the map in Figure 4, the amount of streamflow which was exceeded between 90 and 95 percent of the time was divided by the size of the drainage areas to afford a general indication of water-yielding properties of the rocks within the drainage area.

The map in Figure 4 should be used in connection with other maps of this report in assessing ground-water occurrence and availability. Estimates of the amount of ground water available for development based entirely upon this map might lead to erroneous conclusions. Rocks having both high water storing and water transmitting properties are indicated by the higher discharge areas on the map. Rocks having a high storage capacity but a very low transmitting capacity, such as clay units, or massive indurated sandstone units, show as lower discharge areas on the map. Rocks having high transmitting capacities and lower storage capacities such as glacial deposits also show as lower discharge areas on the map.

Inconsistences between this map and the following one (yield of wells) are due in part to the fact that both maps are necessarily generalized. They are also due to special situations, such as those in the Coastal Plain, where the arbitrary 90% duration does not apply (60% would be better) or in areas where high-yielding wells depend upon induced infiltration from streams. Nevertheless, both maps are useful guides to the general availability of ground water.

GROUND-WATER DISCHARGE



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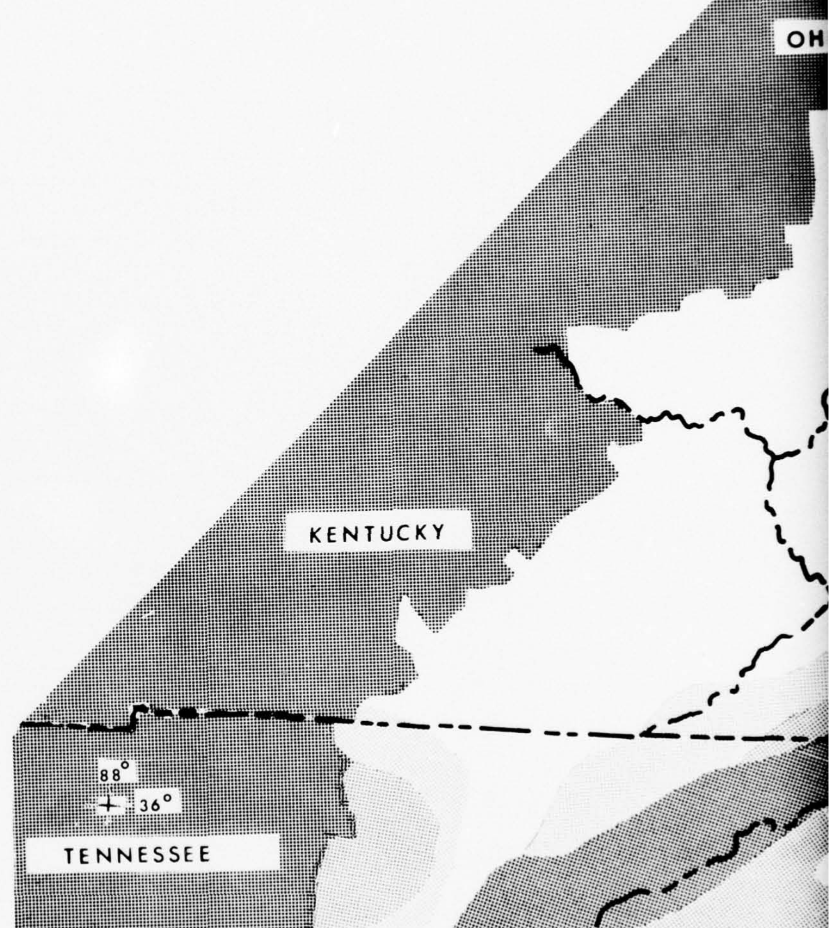


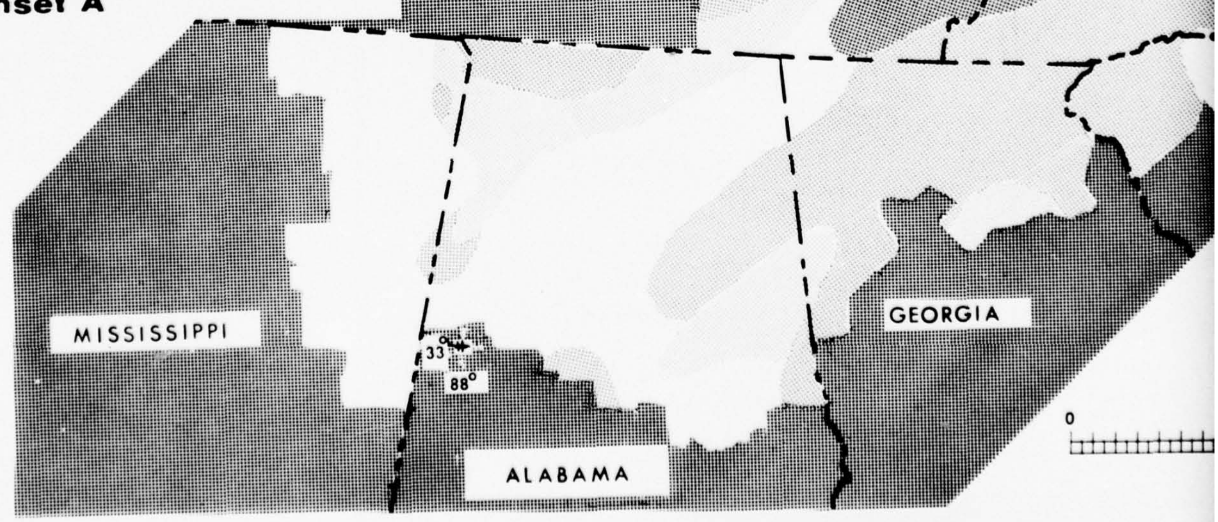
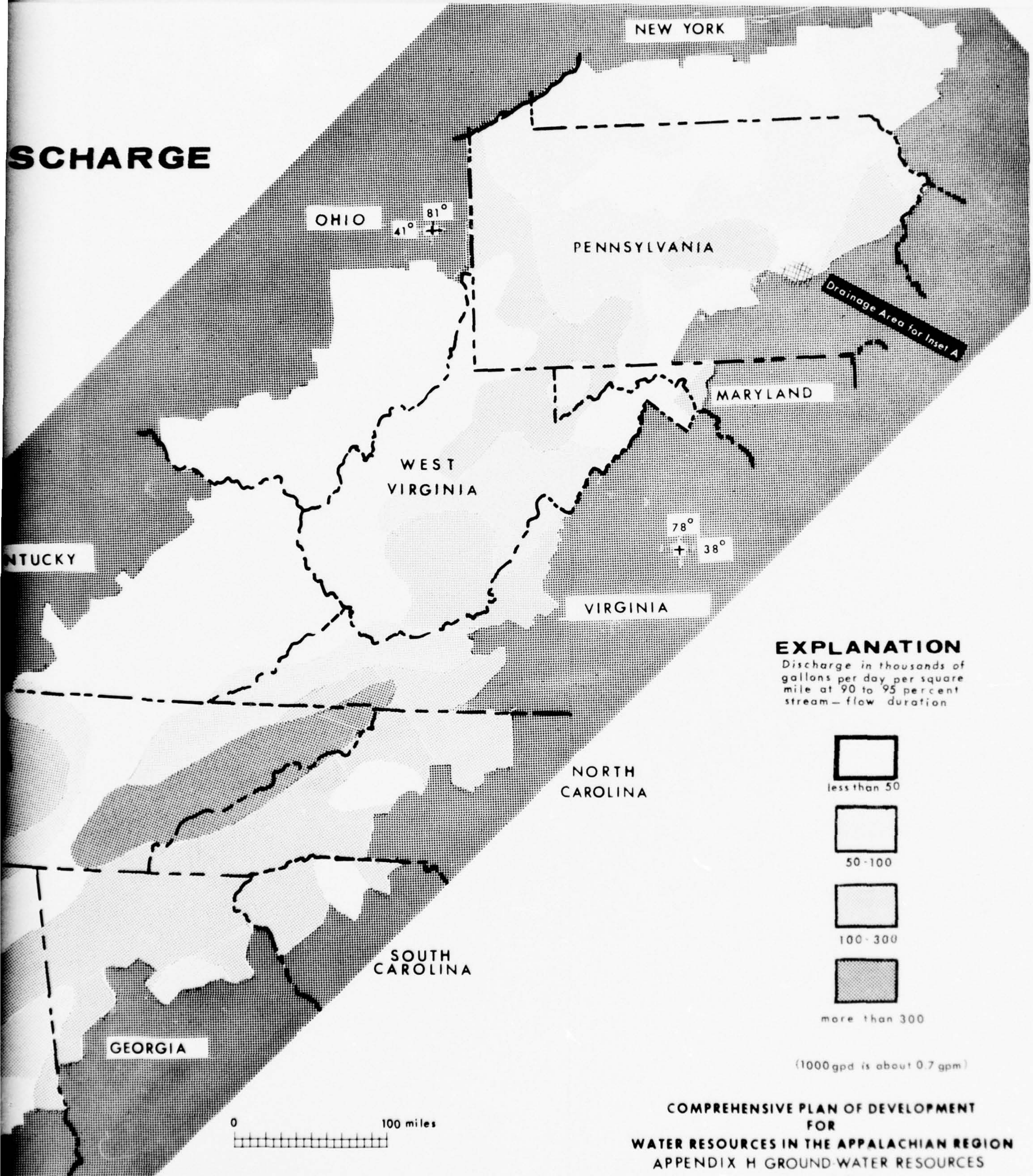


Figure 4.– Ground-Water Discharge to Streams

SCHARGE



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THE YIELD OF WELLS

The maximum yield that may be expected, from individual wells, within each county of the Appalachian Region is shown in Figure 5. The assumption is made that wells will be located, constructed, and developed with care and that the pump equipment will be of the optimum rating and setting for the wells. Under these conditions a capable driller can construct, within each county, one or more wells capable of the indicated yields. It must be understood that these are maximum yields and that not all carefully constructed wells in the areas indicated will be capable of yielding the quantities indicated.

The data for compiling the map came primarily from tables of well records for county or multi-county reports of ground-water resources prepared largely by the U. S. Geological Survey in cooperation with the States. For many counties the data were published, but some unpublished tables were furnished by the District offices of the Survey. Thus, data were available from more than 295 counties in the Appalachian Region. These data included records of more than 24,000 wells. For counties where tables of well records were not available, interpretative reports, such as Hydrologic Atlases and Basin Reports, were used to complete the map.

The data were selected by first deleting wells that were not designed as water wells. Oil and gas test holes frequently had the highest yields within counties but generally supplied water containing undersirable chemical constituents. These were deleted from the tables. Also deleted were records of supplies developed from abandoned mines and from springs, in order to arrive at a maximum yield of water of acceptable quality based entirely upon water-well construction. The average yields of the highest 3 percent of the wells within a county were used as a maximum yield for that county in preparing the map. This approach was used because about 97 percent of the wells reported were drilled for purposes such as rural or domestic water supplies that did not require large quantities of water and no attempt was made to develop the maximum capacity of the rocks. High-yield wells for industrial or municipal water supply should, of course, be constructed at the most promising sites if comparable yields are to be expected.

Several factors affect the occurrence of high-yield sites. In New York, Pennsylvania, Ohio, and the lower Ohio River basin the high-yield sites generally occur in the valleys underlain by glacial outwash deposits.

Yields of wells tapping coarse sand and gravel deposits of glacial origin are reported as high as 3500 gpm. Another factor affecting the yield of wells is the fracturing of folded rocks in the Appalachian Region. Almost every report on ground water in the crystalline rock areas mentions that the ground water occurs in fracture zones of the rocks. The lowest yields of wells occur in the flat-lying, well-indurated rocks where little or no faulting has occurred. The average high yield in some of these areas is less than 10 gpm. The low yields approach zero. However, for special purposes the relatively small temperature change and constant and specific chemical characteristics of ground water may make even small quantities of great economic value.

THE COSTS OF WELL FIELDS

The approximate cost of constructing a well field capable of yielding 1 mgd (million gallons per day) was calculated for each county in the Appalachian Region. The assumption is made that 1 mgd (about 700 gpm) could be obtained from ground-water sources in any county in the Region, if a sufficient number of properly drilled and equipped wells were constructed. A residential community of 10,000 people would require about 1 mgd. For more detailed discussions of present and projected future water needs see Appendix D. The term well field, as used in this report, implies a single well or a group of wells capable of producing a given amount of water. Where more than one well is required to produce the amount, the spacing and configuration of the wells must be determined for each individual field depending on local geologic and hydrologic conditions.

THE MAXIMUM YIELD OF WELLS

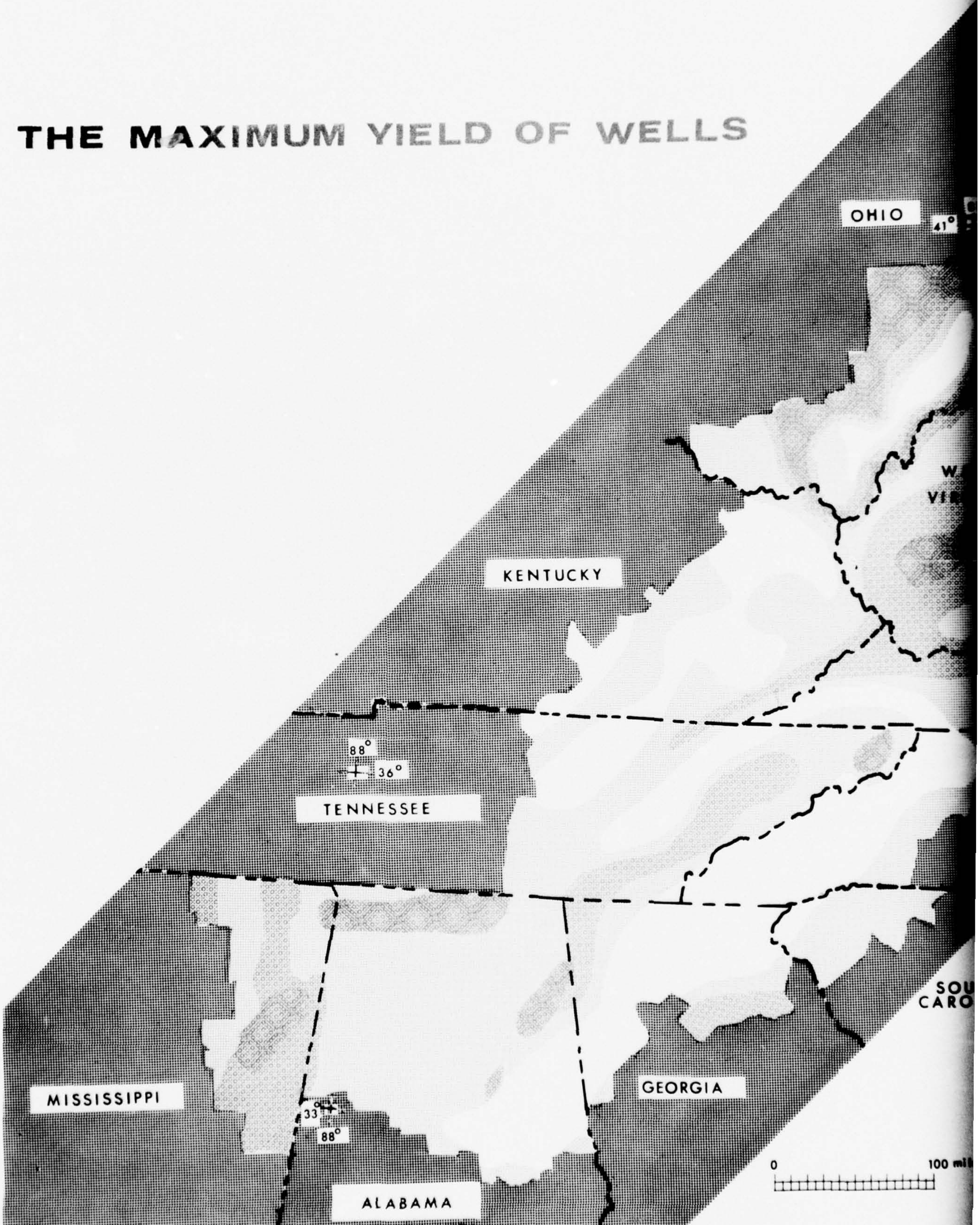
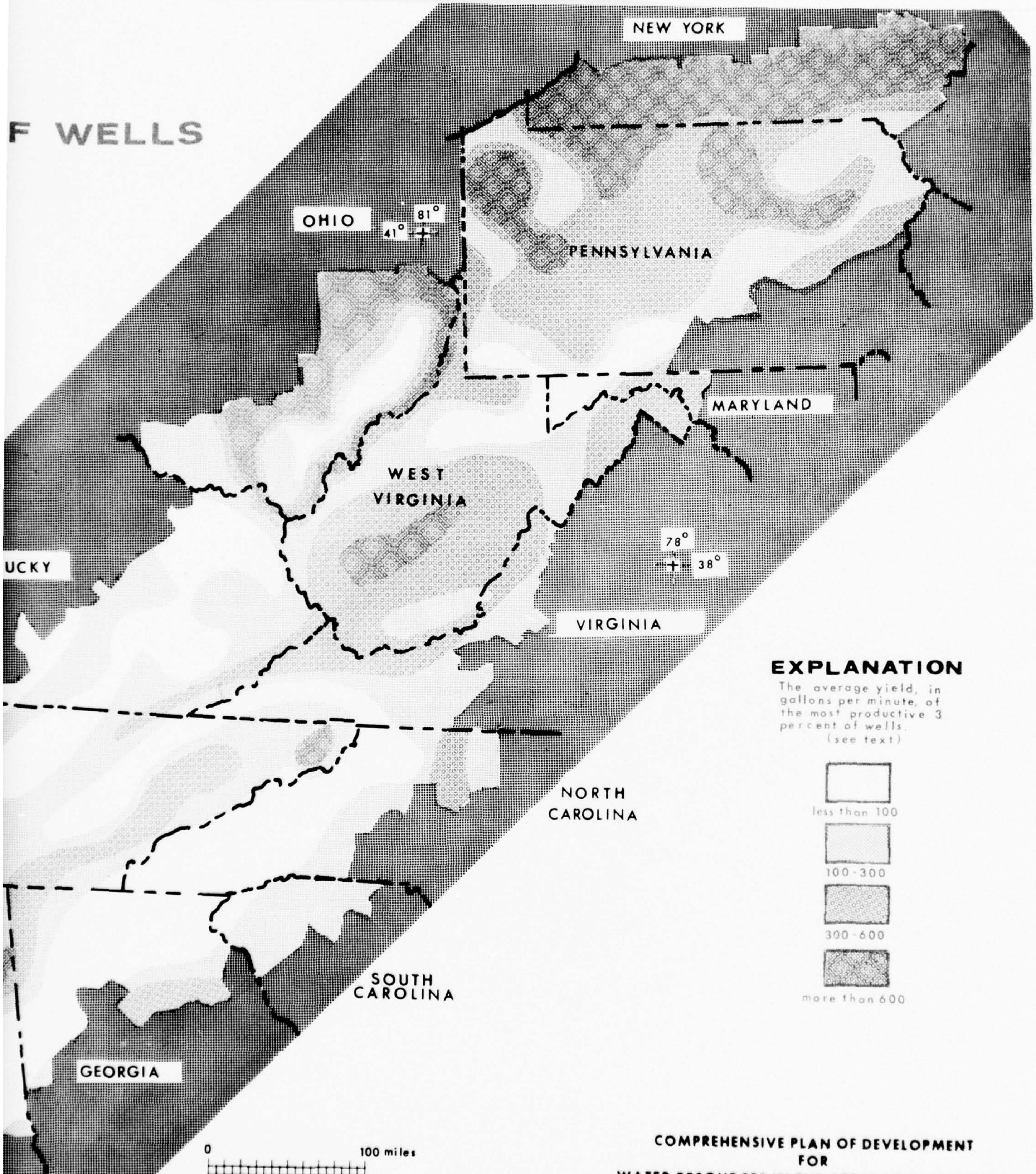


Figure 5.— The Maximum Yield of Wells

F WELLS



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The data used in compiling the map in Figure 6 included; the yield of wells, the depths of wells, the costs of drilling various rock types, the cost of casing and the cost of pumps. Not included were the costs of real estate for well field sites and the cost of exploratory test drilling and test pumping. Costs of real estate are not included because there is no feasible way to determine, on a regional basis, how much land would be required and where the most suitable sites would be in relation to a municipality or industry. In some places, public land is already available for suitable well field development and there would be no additional real estate costs. In other places the most suitable site could be expensive in-town property or inexpensive property outside of the towns.

Costs of exploratory test drilling and test pumping are not included because at some places the first test hole can be converted to a production well that will produce the required water supply and no additional charges are added by the contractor to the cost of construction for exploration. At other places, six to eight test holes might be required before a suitable well site is located. Under these circumstances, additional charges would be made for exploratory drilling. Costs for test pumping would vary with the number of production wells required and the lengths of test required by local hydrologic conditions.

Specific data were available for 296 counties in the Region. Data from regional reports were used for the areas not covered by the detailed reports.

The calculated costs of individual well fields ranged from about $4,000. to about $390,000. In some counties, particularly along major stream valleys containing glacial outwash sediments, a single well may yield more than 5 mgd (about 3500 gallons per minute) from depths of less than 100 feet. In other counties the highest yielding wells are 300 to 400 feet deep and they yield less than 15 gpm, each.

Where individual, shallow wells yield more than 1 mgd, the principal well-field cost is the pumping equipment. Where well yields are low, the principal well-field cost is the drilling cost. As a result of these variables, high costs may occur in some areas of relatively high yields and possibly vice versa.

The divisions on the map in Figure 6 were selected to indicate where ground-water supplies could be obtained at a moderate cost per well field (less than $25,000.). They also indicate where water may be obtained from ground-water sources at a cost generally competitive with other sources ($25,000. to $100,000.). The high-cost division (greater than $100,000) indicates where the development of ground-water supplies is not likely to be the most economical source of large supplies of water.

The costs shown by the divisions are not directly proportionate to the amount of water obtained by the well fields. For example; if a 2 mgd well-field were required the cost in the zones where individual wells produce 2 to 5 mgd would not be twice as much as a 1 mgd well field; the cost would be approximately twice as much where individual wells yield considerably less than 1 mgd.

The costs are calculated on an average cost for drilling and pumps during 1966. Prices are slightly higher than the average shown on the map in the northern part of the Region and slightly lower in the southern part.

THE COST OF WELL FIELDS TO YIELD 1 MILLION GALLONS PER DAY

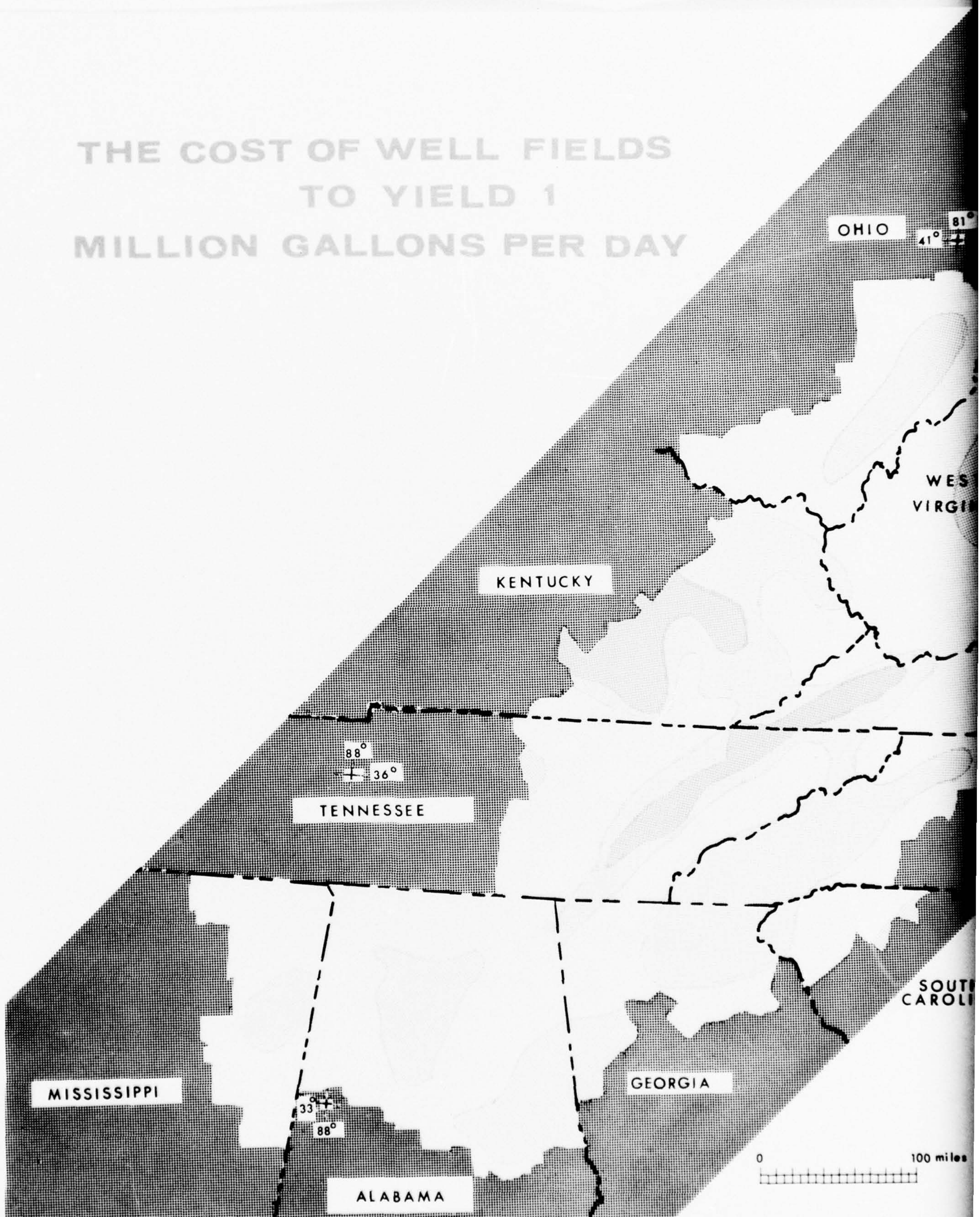

Figure 6.– The Cost of Well Fields To Yield 1 Million Gallons Per Day

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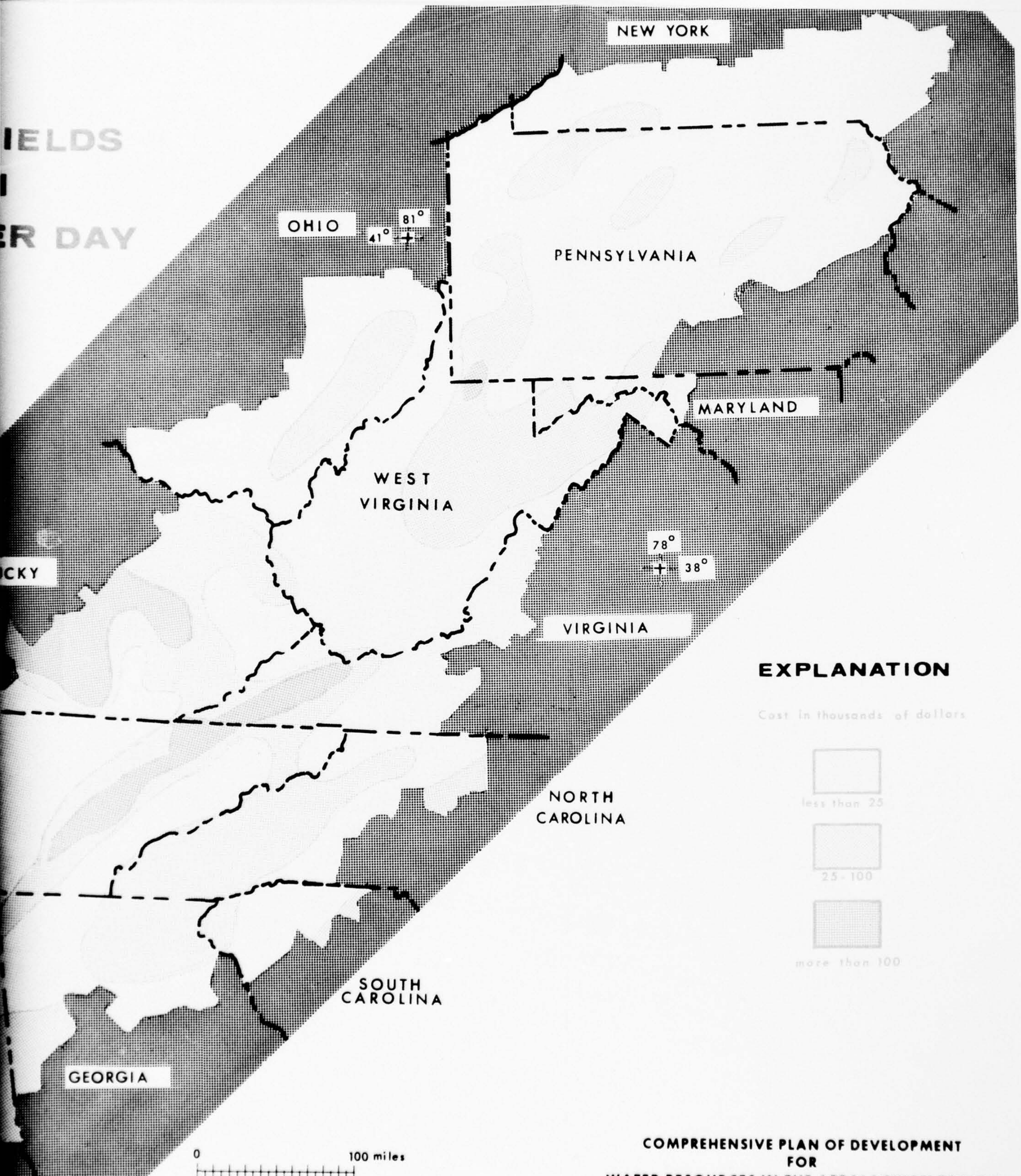

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on Gallons Per Day

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THE COST OF GROUND WATER

Figure 7 is a map showing the approximate minimum cost per thousand gallons of ground water delivered at the well head from well fields obtaining 1 mgd, based upon the assumptions indicated. It was assumed that a well field would be constructed to yield 1 mgd in each county. Each such well field was assumed to be constructed at the optimum site in the county on the basis of yield regardless of location or distance to points of use.

The costs of constructing the well fields have previously been indicated on the map entitled "The Cost of Well Fields". The construction costs were depreciated over a 25-year period at 3¾ percent interest, according to standard interest formulas. The cost of construction and interest were related to a pumping rate of 1 mgd for a 25-year period to derive an "overhead" cost per 1000 gallons.

The cost of pumping was based upon an assumed electric power rate of $0.025 per kilowatt hours. The power used to pump 1 mgd was based upon 90 percent pump efficiency and continuous 24-hour pumpage at sufficient horsepower to lift 1 mgd against the total estimated head. The daily cost of pumping was related to 1 mgd to derive a "pumping" cost per 1000 gallons.

The sum of the overhead and the pumping costs for each county gives a cost per 1000 gallons of water at the well head. This cost does not include water treatment, nor does it include cost of land, of exploratory drilling, or of testing. The cost of water shown on the map indicated the approximate minimum cost by counties. The cost of water in amounts less than 1 mgd would generally be less than the cost shown if a single well supplies all of the required water. The cost of water in amounts greater than 1 mgd would be the same as that shown on the map, except that where individual wells yield more than 1 mgd the cost of water per 1000 gallons would be less than that shown.

Those contemplating the development of ground-water supplies in the Region should use these cost figures only for preliminary comparisons similar to their intended uses in regional planning. For the actual location and design of well fields competent geologic and engineering advice should be sought.

OPTIMUM GROUND-WATER DEVELOPMENT AT COMPUTED COSTS

The optimum amount of ground water, in gallons per day per square mile, that may be developed in the Region at computed costs is shown on Figure 8. The map is not intended to and does not indicate the maximum amount of ground water that is available for development. In most counties the optimum amount shown is between 25 percent and 50 percent of the maximum amount available under existing natural conditions. The optimum amount of ground water is based upon cost figures used in previous parts of this report and the development of ground water in the amount indicated on Figure 8 would be within those costs.

The calculations of the optimum amount of ground water available for development include the depletion of runoff in smaller tributaries where ground-water supply is derived from direct infiltration from streams. As in all areas where total water resources development is contemplated, <u>diverting water from one source may drastically effect the water available from other sources</u>.

In parts of Appalachia where unconsolidated deposits occur in minor tributaries, high-yield wells may be developed at moderate to low cost. The development plan for such areas must recognize not only pumping and construction cost but also the depletion of surface water available from the streams. Conversely, the depletion of surface-water supplies may drastically reduce the amount of ground-water available. The map in Figure 8 was designed so that the indicated optimum development of aquifers will not drastically affect the flow of adjacent small streams.

Two principal factors were used to calculate the optimum development of ground water. The first factor is the amount of ground-water discharge that may be salvaged for use, without the areal lowering of ground-water levels. The second factor is the additional amount of ground water that is available from runoff salvage by areal lowering of the water levels to the depths used in previous parts of the report for the calculated pumping costs. The sum of the two factors is taken as the optimum amount of ground water for development. These factors were used for calculations throughout the Region, except along major streams containing thick, well-sorted sediments that allow stream infiltration to well fields. Along such streams, where the stated low flow exceeded 500,000 gpd (gallons per day), the calculations were based upon well spacing and pumping rates.

The development of ground water in excess of the amounts indicated on this map is possible and has occurred in places but the costs increase considerably over those given in previous sections of this report.

COST OF GROUND WATER

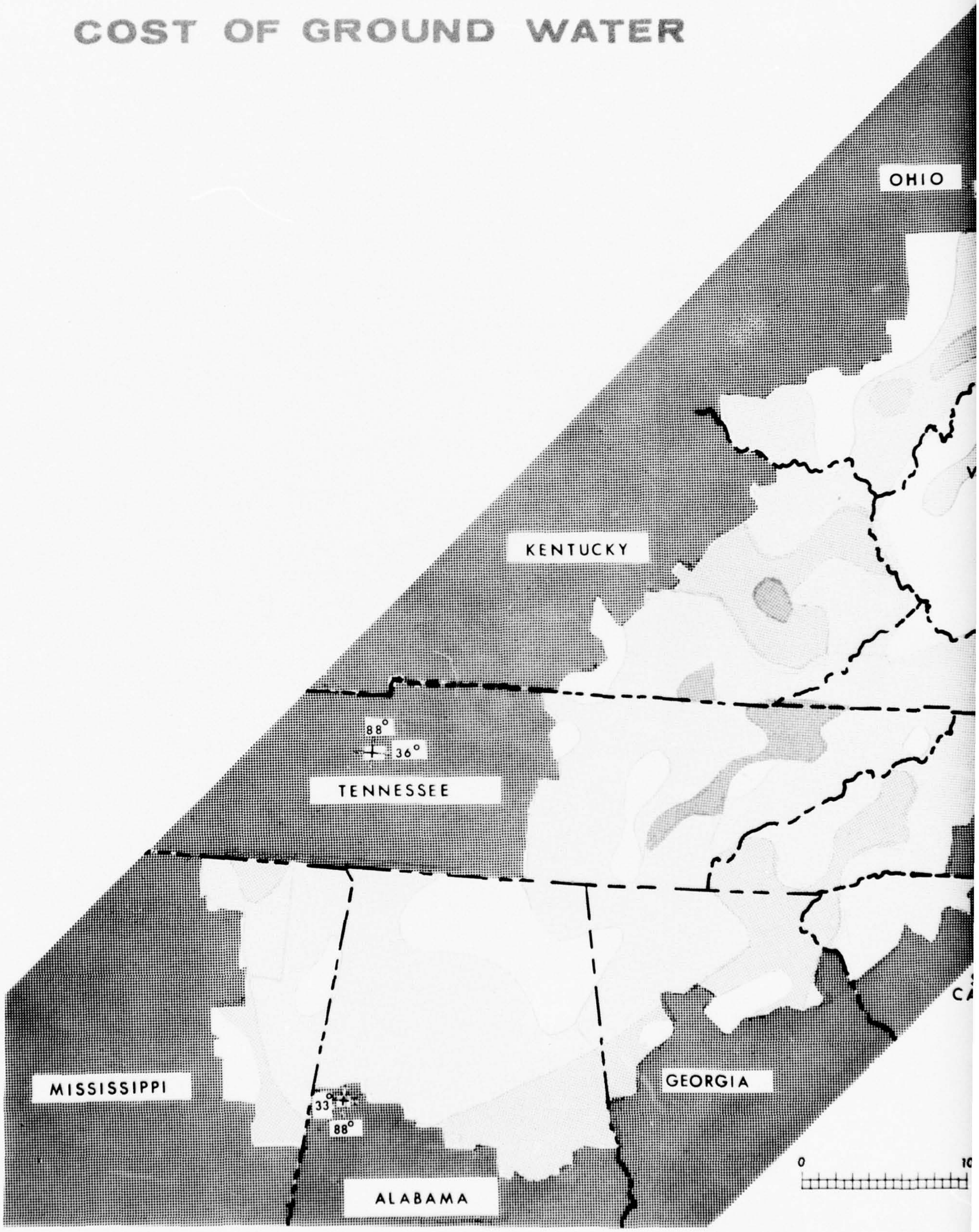

Figure 7.– The Cost of Ground Water

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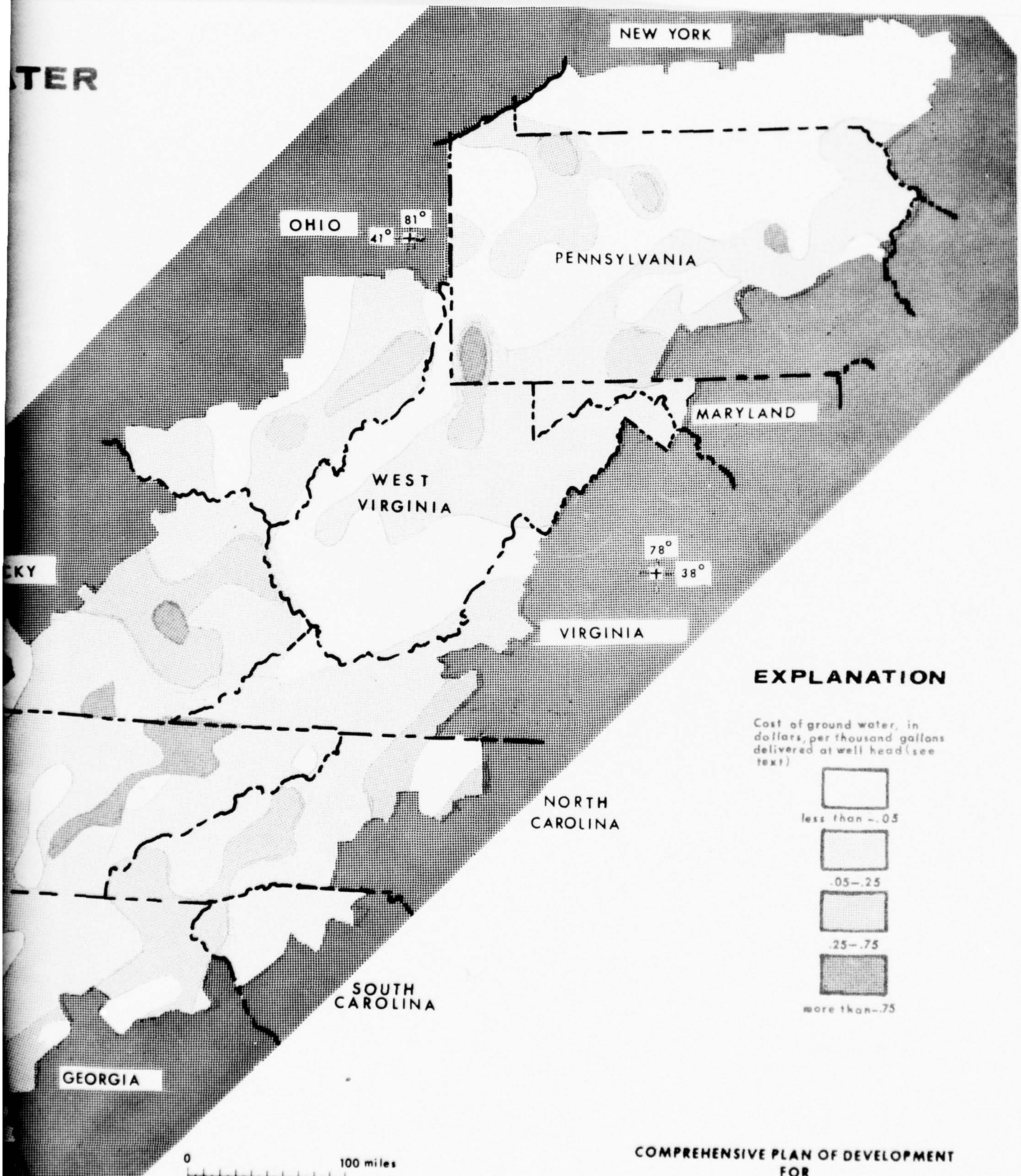

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OPTIMUM GROUND-WATER DEVELOPMENT

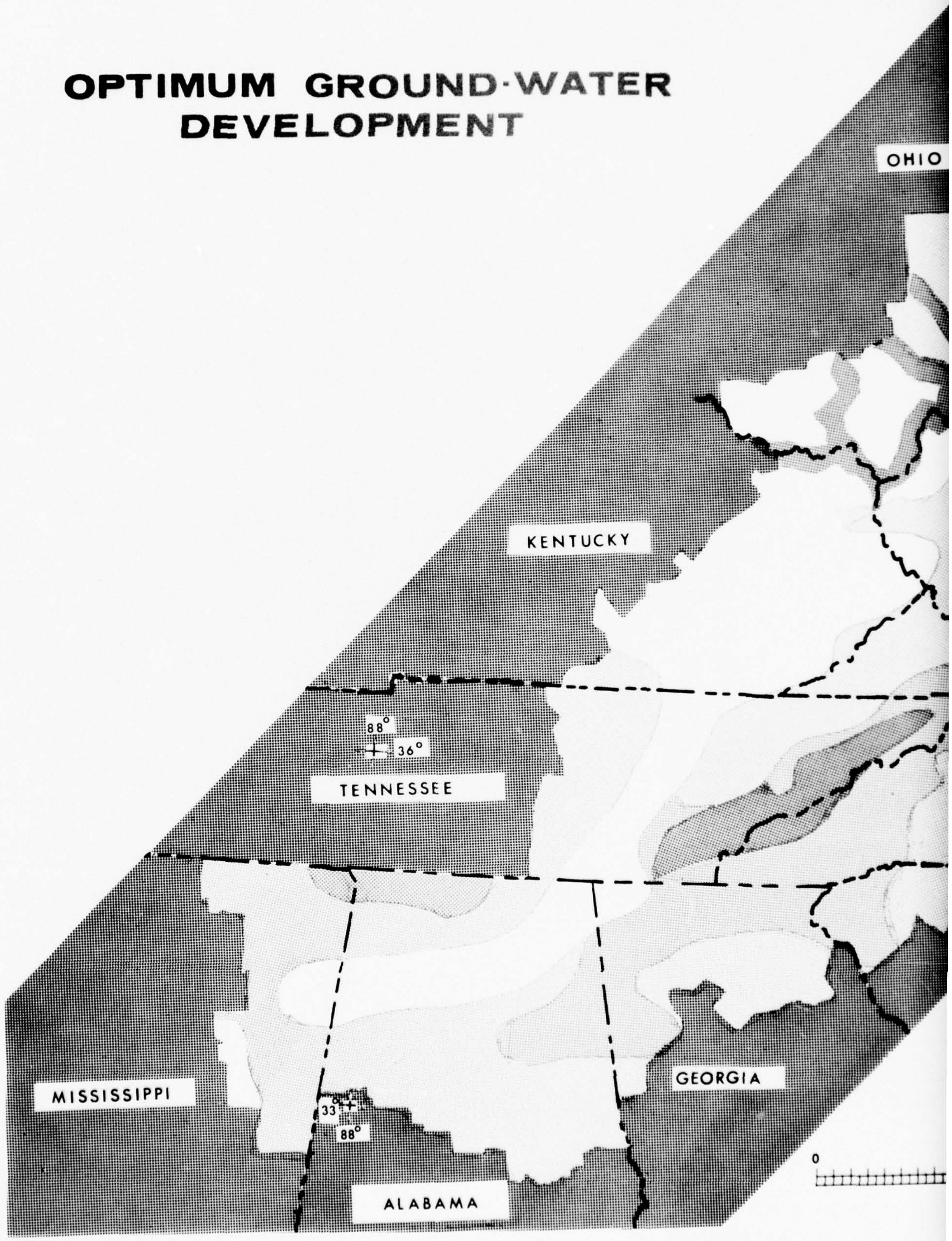

Figure 8.- Optimum Ground-Water Development at Stated Cost

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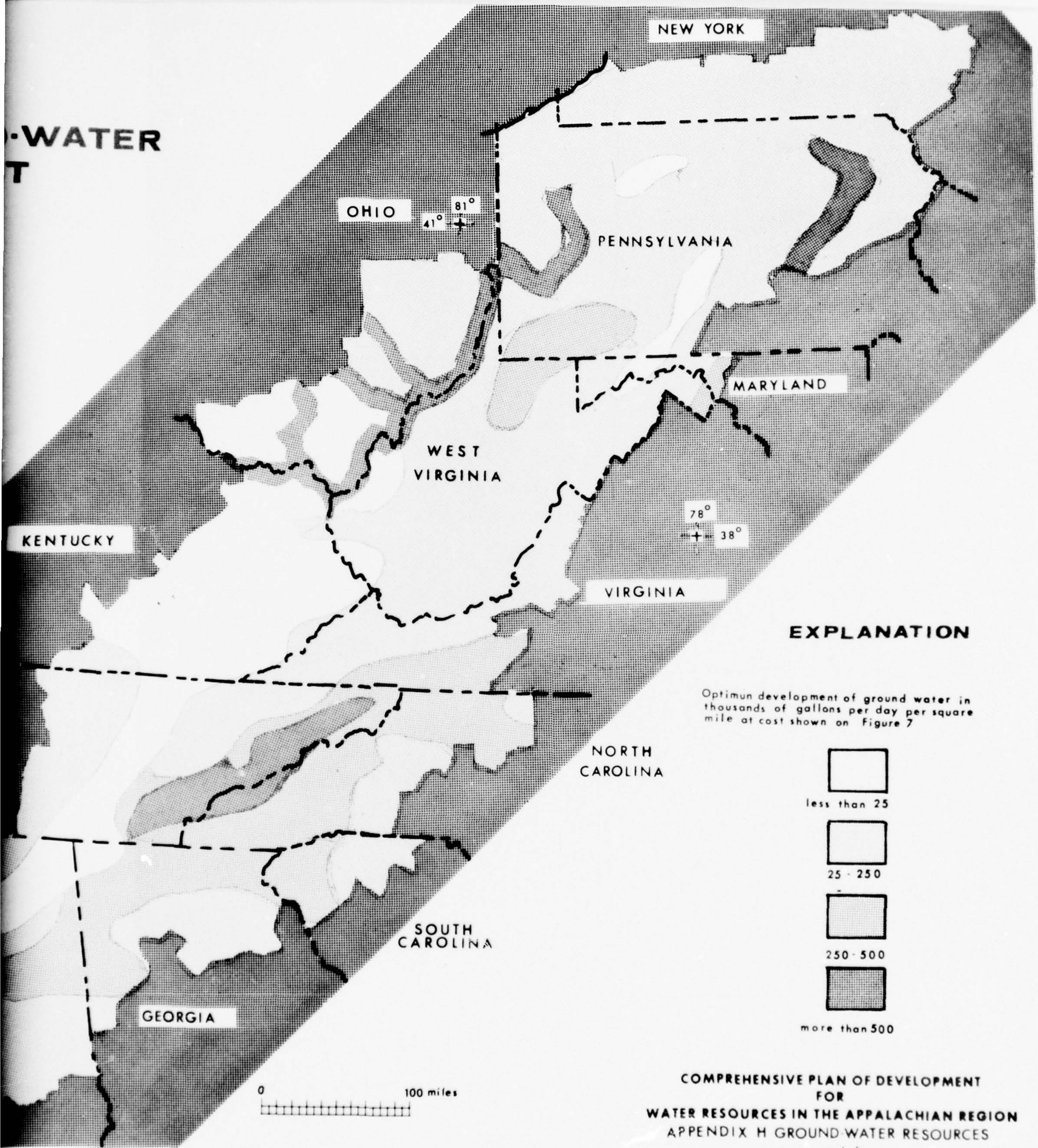

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Cost

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PART II

SUMMARY OF GROUND-WATER RESOURCES BY SUB-REGION

The Appalachian Region has been divided into ten Sub-Regions. The boundaries of the Sub-Regions were based upon several factors including economic regions, drainage areas and areas of responsibility for parts of the overall report on the Region. The locations of the Sub-Regions are shown in Figure 9. Because many agencies of the Appalachian Study will prepare reports based upon the designated Sub-Regions, the summary of the generalized study of ground-water resources will be more usable if also presented by Sub-Regions. The following section gives a brief description of the ground-water resources of each Sub-Region.

Sub-Region A

Water Sub-Region A is in the northeastern part of the Appalachian Region, lies entirely within the State of Pennsylvania and includes parts of two physiographic provinces. The northern part of the Sub-Region is in the Appalachian Plateaus province, and the southern part is in the Valley and Ridge province.

The Sub-Region is underlain by rocks of Devonian, Mississippian, and Pennsylvanian ages. The rocks are predominantly shale with interbedded limestone, siltstone, and sandstone. Most of the Sub-Region, except the extreme southwestern part, is within an area that was subjected to glaciation. During and subsequent to glaciation, reworked, sorted glacial material has been deposited by streams in the major stream valleys.

Ground water occurs in the intergranular pore space of the glacial-alluvium deposits and in fractures in the bedrock units. The fractures in bedrock result from major faulting in the southern part and the folding of bedrock in the southern and western parts of the Sub-Region.

The ground-water discharge, at about 90 percent streamflow duration, is between 50 and 100 thousand gpd per square mile in the northern and western part of the Sub-Region and between 100 and 300 thousand gpd per square mile in the eastern part. Individual wells, properly located and constructed, in the northern part of the Sub-Region may yield between 100 and 300 gpm. In the west-central part they may yield more than 600 gpm. The average depths of the high-yield wells are greater than 500 feet except along the eastern edge of the Sub-Region where the high-yield wells are between 250 and 500 feet deep.

A well field capable of producing 1 mgd would cost between 25 and 100 thousand dollars to construct in the northwestern part of the Sub-Region. Throughout the remainder of the Sub-Region a well field capable of producing 1 mgd would cost between 6 and 25 thousand dollars for construction. The cost of producing ground water, based upon 1 mgd and including pumping costs, construction costs and interest on construction costs for a 25-year period, for raw water delivered at the well head, would be between $0.05 and $0.25 per thousand gallons in most of the Sub-Region except the southeastern and west-central parts where it would be less than $0.05 per thousand gallons. The optimum development of ground water at these costs would be between 25 and 250 thousand gpd per square mile in the eastern part and more than 500 thousand gpd per square mile in the western part of the Sub-Region.

Sub-Region B

Water Sub-Region B is in the north-central part of the Appalachian Region, and includes parts of four states, New York, Pennsylvania, Maryland, and West Virginia. Sub-Region B is in parts of three physiographic provinces; the northern and western parts are in the Appalachian Plateaus province, the southern and central parts are in the Valley and Ridge province, and a few east-central counties are within the Blue Ridge province.

The rocks that underlie the Sub-Region range from Cambrian to Pennsylvanian in age. Essentially flat-lying shales and sandstones of Devonian age underlie the northern part of the Sub-Region. The rocks, primarily shale with interbedded limestone and sandstone, of the central and southern parts of the Sub-Region are folded and their outcrops trend northeast-southwest. The northern part of the Sub-Region is within the area that was subjected to glaciation. Outwash of glacial material has been sorted and redeposited in the major stream valleys in the northern part of the Sub-Region, resulting in conditions favorable to the production of ground water.

Ground water occurs in the intergranular pore space of the glacial-alluvium deposits in the stream valleys in the northern part of the Sub-Region. In the northwestern and central parts ground water occurs, in quantity, in fractures of the basement rock that result from major faulting. Ground water also occurs in the fractures of basement rock, resulting from folding of the rocks, along the eastern part of the Sub-Region.

Ground-water discharge, at about 90 percent streamflow duration, is between 50 and 100 thousand gpd per square mile in the northeastern, west-central and southern parts of the Sub-Region.

WATER SUB-REGIONS

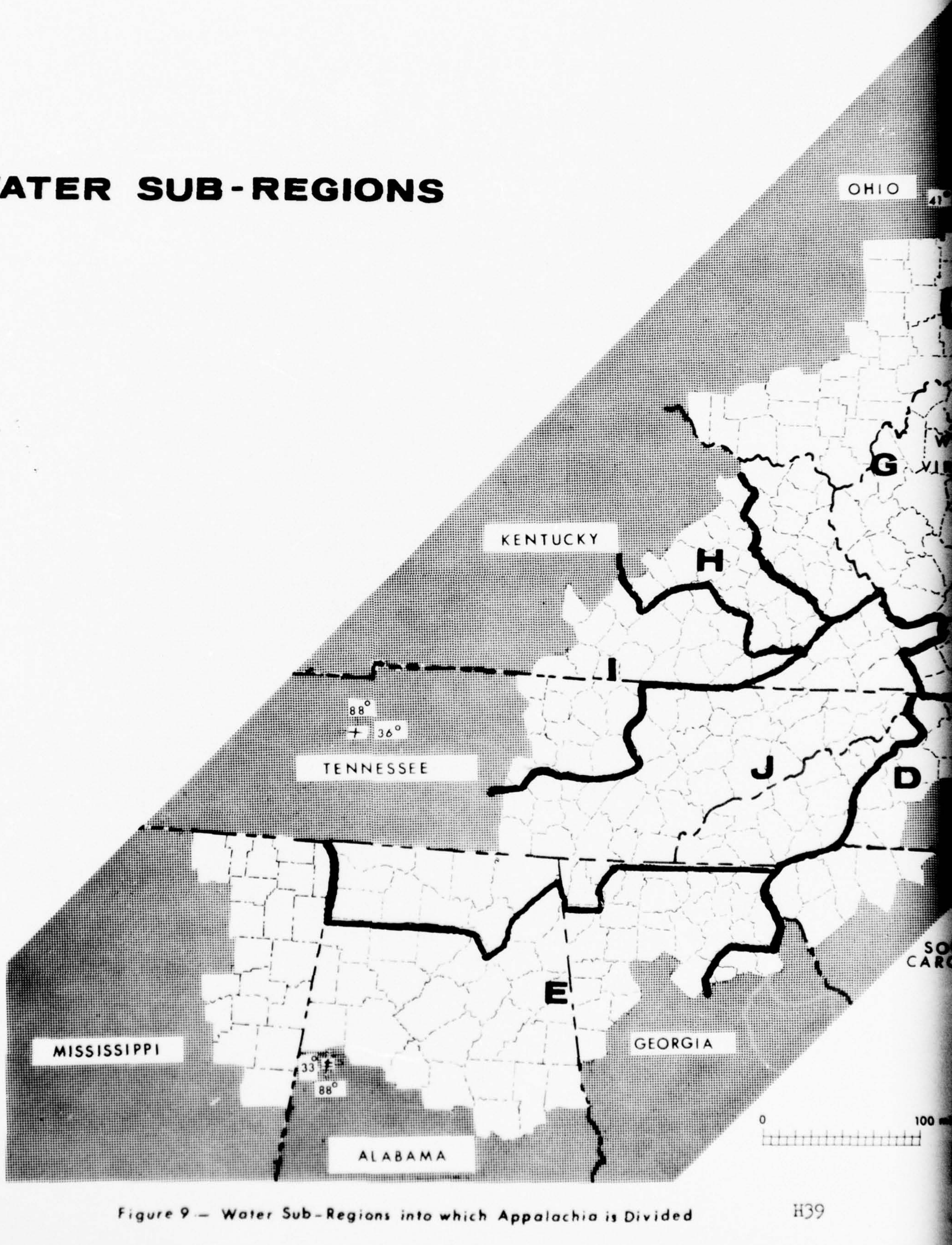
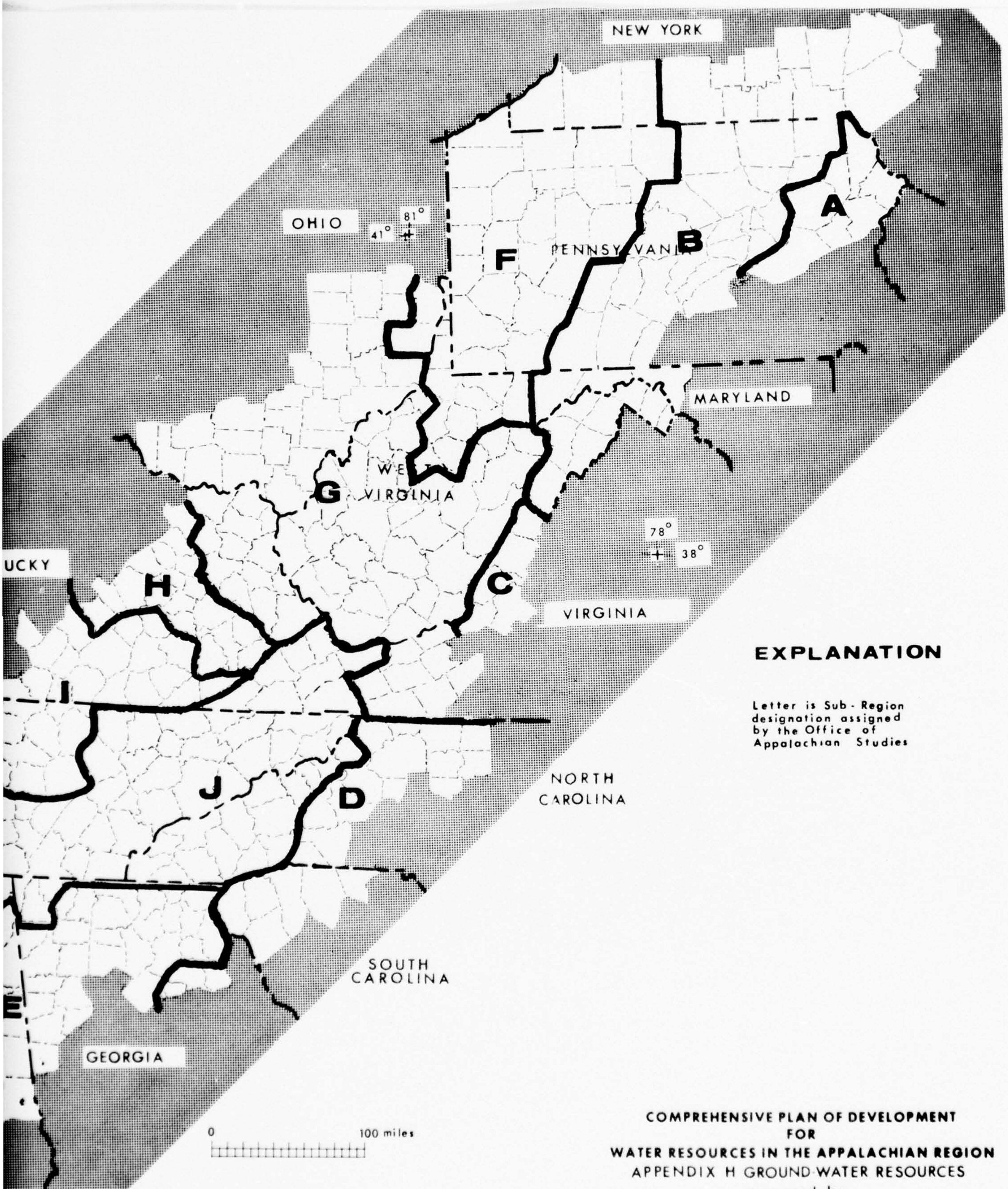


Figure 9 — Water Sub-Regions into which Appalachia is Divided



EXPLANATION

Letter is Sub - Region designation assigned by the Office of Appalachian Studies

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The discharge is less than 50 thousand gpd per square mile in the northwestern and southeastern parts, and between 100 and 300 thousand gpd per square mile in the central parts of the Sub-Region. Individual wells, properly located and constructed, may yield more than 600 gpm in the northern and north-central parts, between 300 and 600 gpm in the southeastern and west-central parts, and between 3 and 100 gpm in the southwestern part of the Sub-Region. The average depths of high-yield wells in the northwestern and east-central parts of the Sub-Region are between 125 and 250 feet. In the southern part they are more than 500 feet deep and in the remainder of the Sub-Region the wells are between 250 and 500 feet deep.

The construction of a well field capable of producing 1 mgd would cost less than 25 thousand dollars in most of the Sub-Region except the southern and east-central parts where it would cost between 25 and 100 thousand dollars. The cost per thousand gallons for producing ground water at 1 mgd, including pumping costs, construction and interest on construction costs for a 25-year period would be less than $0.05 per thousand gallons in the northern part, between $0.05 and $0.25 per thousand gallons in the southern part and between $0.25 and $0.75 per thousand gallons in the east-central part of the Sub-Region. The optimum development of ground water at these costs would be between 25 and 250 thousand gpd per square mile throughout most of the Sub-Region except the central part where it is less than 25 thousand gpd per square mile, and the southeastern and east-central parts where it would be between 250 and 500, and more than 500 thousand gpd per square mile respectively.

Sub-Region C

Water Sub-Region C is in the east-central part of the Appalachian Region, lies entirely in the State of Virginia, and is included in the Valley and Ridge and Blue Ridge provinces.

The Sub-Region is underlain by rocks that range from Precambrian to Devonian in age. The oldest rocks outcrop in the eastern part of the Sub-Region and the youngest outcrop in the western part. The rocks are predominantly shale and limestone with interbedded sandstone and siltstone.

Ground water occurs, primarily, in the fractures and fault zones that increase the permeability of the bedrock units. The major fault zones are in the southern part of the Sub-Region but fracturing resulting from the folding of bedrock occurs throughout the Sub-Region.

The ground-water discharge at about 90 percent streamflow duration is between 50 and 100 thousand gpd per square mile in the northwestern part of the Sub-Region. The ground-water discharge is between 100 and 300 thousand gpd per square mile in the remaining part. Individual wells, properly located and constructed, will yield between 100 and 300 gpm in the southeastern part and between 300 and 600 gpm in the north and western parts of the Sub-Region. The average depths of the high-yield wells are between 250 and 500 feet below land surface in the northern part of the Sub-Region and more than 500 feet below land surface in the southern part.

A well field capable of producing 1 mgd would cost less than 25 thousand dollars to construct throughout the Sub-Region. The cost of producing ground water, based upon 1 mgd and including pumping costs, construction costs and interest on construction costs for a 25-year period for raw water delivered at the well head would be less than $0.05 per thousand gallons in the northern part and between $0.05 and $0.25 per thousand gallons in the southern part of the Sub-Region. The optimum development of ground water at these costs would be between 25 and 250 thousand gpd per square mile throughout the Sub-Region.

Sub-Region D

Water Sub-Region D is in the southeastern part of the Appalachian Region, and includes parts of three states, North Carolina, South Carolina, and Georgia. Most of the Sub-Region is in the Piedmont province, but the westernmost part is in the Blue Ridge province.

The Sub-Region is underlain by rocks of Precambrian and Paleozoic age. The rocks, predominantly gneiss and schist with some interbedding of sandstone, have been locally subjected to igneous intrusives.

Ground water occurs in fracture openings in the rocks resulting from faulting in the westernmost part of the Sub-Region and fractures that result from folding in the northwestern part of the Sub-Region. Ground water also occurs in the intergranular pore space of the bedrock in the eastern part of the Sub-Region.

The ground-water discharge at about 90 percent streamflow duration is between 100 and 300 thousand gpd per square mile in most of the Sub-Region except northwestern South Carolina and western North Carolina where the discharge is less than 50 thousand gpd per square mile and in north-central Georgia where it is between 50 and 100 thousand gpd per square mile.

Individual wells properly located and constructed will produce between 100 and 300 gpm in most of the Sub-Region except in the northeastern and southern parts where the yield is between 300 and 600 gpm and the westernmost part where it is less than 100 gpm. The average depth of the high-yield wells are between 250 and 500 feet below land surface throughout most of the Region except in the northeast and east-central parts of the Sub-Region where the depths are more than 500 feet below land surface.

A well field capable of producing 1 mgd would cost less than 25 thousand dollars for construction in the central part and between 25 and 100 thousand in the eastern and western part of the Sub-Region. The cost of producing ground water, based upon 1 mgd and including pumping cost, construction costs and interest for a 25-year period on construction cost, for raw water delivered at the well head, would be between $0.05 and $0.25 per thousand gallons through most of the Sub-Region except the northeastern and southwestern parts where it would be less than $0.05 per thousand gallons in some places and between $0.25 and $0.75 in others. The optimum development of ground water at these costs would be between 250 and 500 thousand gpd per square mile in the northern and southern parts and between 25 and 250 thousand gpd per square mile in the central part and the extreme southwestern and northeastern parts of the Sub-Region.

Sub-Region E

Water Sub-Region E is in the southern part of the Appalachian Region. The Sub-Region includes parts of three states, Mississippi, Georgia, and Alabama, and is included in parts of five physiographic provinces. The eastern part is in the Piedmont province, the central part in the Blue Ridge and the Valley and Ridge provinces, the central-western part in the Appalachian Plateaus and the southern and westernmost parts of the Sub-Region are in the Coastal Plain province.

The Sub-Region is underlain by rocks that range from Precambrian to Tertiary in age. The Precambrian and Paleozoic rocks are predominantly gneiss, schist, and sandstone injected by igneous material. The Cretaceous rocks are primarily interbedded sand and clay layers that are unconsolidated.

Ground water occurs in the openings resulting from major faulting and folding in the central and northeastern parts of the Sub-Region. Ground water also occurs in the intergranular pore space of the sandbeds in the southern and western parts of the Sub-Region.

The ground-water discharge, at about 90 percent streamflow duration is less than 50 thousand gpd per square mile in the northeastern and southwestern part of the Sub-Region. The discharge is between 50 and 100 thousand gpd per square mile in the north-central part and between 100 and 300 thousand gpd per square mile in the south-central part of the Sub-Region. Individual wells properly located and constructed along the Ohio River in the western part and in the glacial deposits in the west-central and northern parts will produce more than 600 gpm. Throughout most of the remaining Sub-Region the wells will produce between 300 and 600 gpm except in the southern part and some places in the northwestern part where the yield is less than 300 gpm. The average depths of high yield wells are between 250 and 500 feet below land surface except in the northern part of the Sub-Region where the depths are between 125 and 250 feet below land surface and along the Ohio River where the depths are between 50 and 125 feet below land surface.

A well field capable of producing 1 mgd would cost between 4 and 25 thousand dollars throughout most of the Sub-Region except in the northeast and southern parts where the costs would be between 25 and 100 thousand dollars. The cost of producing ground water, based upon 1 mgd and including pumping cost, construction costs and interest for a 25-year period on construction costs, for raw water delivered at the well head would cost less than $0.05 per thousand gallons throughout most of the Region except the north-central part where the cost would be between $0.05 and $0.25 per thousand gallons, and the southwestern part where the cost would be greater than $0.75 per thousand gallons. The optimum development of ground water at these costs would be between 25 and 250 thousand gpd per square mile in most of the Sub-Region except the southern part where it would be between 250 and 500 thousand gpd per square mile, along the Allegheny River where it would be more than 500 thousand gpd per square mile and in the northeastern part where it would be less than 25 thousand gpd per square mile.

Sub-Region G

Water Sub-Region G is in the west-central part of the Appalachian Region, where it includes parts of four states, Ohio, West Virginia, Virginia and Kentucky. The Sub-Region also lies within parts of five physiographic provinces, the Blue Ridge, Valley and Ridge, Appalachian Plateaus, the Interior Low Plateaus, and the Central Lowlands.

The Sub-Region is underlain by rocks that range from Precambrian to Permian in age. Deposits of glacial outwash occur in the major stream valleys in the northern and westernmost part of the Sub-Region. The rocks are, for the most part, massive, flat-lying, sandstone, shale, and limestone units.

Ground water occurs in the glacial-alluvial deposits along the stream valleys of the Ohio River and its northern tributaries in the western part of the Sub-Region and in the intergranular pore space and fracture zones in sandstone and shale in the eastern and southern parts.

Ground-water discharge at about 90 percent streamflow duration is less than 50 thousand gpd per square mile throughout the northern and western parts and ranges from 50 to 300 thousand gpd per square mile in the eastern and southern parts of the Sub-Region. Individual wells properly located and constructed will yield more than 600 gpm in stream valleys in the central and northwestern parts of the Sub-Region and along the Ohio River and its tributaries. Throughout the remainder of the Sub-Region the wells at selected sites in each county will yield between 100 and 300 gpm except in the northeastern part where yields are less than 100 gpm. The average depths of high yield wells are between 50 and 250 feet throughout the Sub-Region except along the major streams where the depts are between 50 and 125 feet.

A well field capable of producing 1 mgd would cost between 4 and 25 thousand dollars to construct except in the west-central, north-central, and east-central parts of the Sub-Region where the cost would be between 25 and 100 thousand dollars. The cost of producing ground water based upon 1 mgd and including pumping cost, construction costs and interest for a 25-year period on construction costs, for raw water delivered at the well head would be less than $0.05 per thousand gallons in the central part and along the northwestern boundary of the Sub-Region. In the east-central, northeastern, southeastern and western parts, the costs would be between $0.05 and $0.25 per thousand gallons and in the southwest and north-central parts of the Sub-Region the costs would be between $0.25 and $0.75 per thousand gallons. The optimum development of ground water at these costs would be between 25 and 250 thousand pgd per square mile in the eastern and northern parts of the Sub-Region, less than 25 thousand gpd per square mile in the western part and more than 500 thousand gpd per square mile along the Ohio River and its tributaries.

Sub-Region H

Water Sub-Region H is in the west-central part of the Appalachian Region. The Sub-Region lies entirely within the commonwealth of Kentucky, and includes parts of two physiographic provinces. Most of the Sub-Region is in the Appalachian Plateaus province. The northwestern part of the Sub-Region is in the Interior Low Plateaus province.

The Sub-Region is underlain by rocks that range from Ordovician to Pennsylvanian in age. The rocks are, for the most part, massive, flat-lying limestone, sandstone, and shale.

Ground water occurs in the bedrock units in the openings associated with major faults in the western part of the Sub-Region and the openings associated with fractures and intergranular pore space in the sandstone and shale in the eastern part of the Sub-Region.

Ground-water discharge at about 90 percent streamflow duration is less than 50 thousand gpd per square mile throughout the Sub-Region. Individual wells properly located and constructed will yield between 3 and 100 gpm in the central part, and between 100 and 300 gpm in the southeastern and northwestern parts, and between 300 and 600 gpm in the extreme southeastern part of the Sub-Region. The average depths of the high-yield wells in the western part are between 125 and 250 feet below land surface and in the eastern part of the Sub-Region the depths are between 250 and 500 feet below land surface.

A well field capable of producing 1 mgd would cost between 4 and 25 thousand dollars to construct in the southeastern part, between 25 and 100 thousand dollars in the central part, and more than 100 thousand dollars to construct in the northwestern part of the Sub-Region. The cost of producing ground water based upon 1 mgd and including pumping costs, construction costs and interest for a 25-year period on construction costs for raw water delivered at the well head would be between $0.25 and $0.75 per thousand gallons in the central part of the Sub-Region except the west-central part where the cost would be greater than $0.75 per thousand gallons, and the northeastern, southeastern and extreme western corners where the costs would be between $0.05 and $0.25 per thousand gallons. The optimum development of ground water at these costs would be less than 25 thousand gpd per square mile throughout the Sub-Region except the extreme southeastern corner where it would be between 25 and 250 thousand gpd per square mile.

Sub-Region I

Water Sub-Region I is in the southwestern part of the Appalachian Sub-Region. The Sub-Region includes parts of two states, Tennessee and Kentucky, and parts of two physiographic provinces - the Appalachian Plateaus province and the Interior Low Plateaus province.

The Sub-Region is underlain by rocks that range from Ordovician to Pennsylvanian in age. The rocks are generally massive sandstones, limestones, and shales.

Ground water occurs in the openings associated with major faults and folded rock in the eastern part and in the intergranular pore space and in fracture zones in the western part of the Sub-Region.

Ground-water discharge at about 90 percent stream flow duration is less than 50 thousand gpd per square mile in the northern and eastern parts, between 50 and 100 thousand gpd per square mile in the central part, and between 100 and 300 thousand gpd per square mile in the southwestern part of the Sub-Region. Individual wells properly located and constructed will yield between 300 and 600 gpm in a small area in the eastern part, between 100 and 300 gpm in the eastern and west-central parts, and less than 100 gpm in the central and northwestern parts of the Sub-Region. The average depths of the high yield wells are between 250 and 500 feet below land surface in the northeastern part of the Sub-Region and between 125 and 250 feet below land surface throughout the rest of the Sub-Region.

A well field capable of producing 1 mgd would cost less than 25 thousand dollars to construct in the southwestern and east-central parts, between 25 and 100 thousand dollars to construct in the northeastern part, and more than 100 thousand dollars to construct in the northwestern part of the Sub-Region. The cost of producing ground water, based upon 1 mgd and including pumping cost, construction costs and interest for a 25-year period on construction costs, for raw water delivered at the well head would be between $0.05 and $0.25 per thousand gallons throughout most of the Sub-Region except the central part where the costs would be more than $0.75 per thousand gallons and the northeastern part where the costs would be between $0.25 and $0.75 per thousand gallons and in the northwestern and extreme southeastern parts it would be less than $0.05 per thousand gallons. The optimum development of ground water at these costs would be less than 25 thousand gpd per square mile throughout most of the Sub-Region except the southwestern part where it is between 25 and 250 thousand gpd per square mile.

Sub-Region J

Water Sub-Region J is in the southwestern and south-central parts of the Appalachian Region. The Sub-Region includes parts of five states, Tennessee, North Carolina, Alabama, Virginia, and Georgia and parts of five physiographic provinces - the Appalachian Plateaus, the Interior Low Plateaus, the Coastal Plain, the Valley and Ridge and the Blue Ridge provinces.

The Sub-Region is underlain by rocks that range from Precambrian to Cretaceous in age. In the eastern and central parts of the Sub-Region, sandstones, shales and meta-volcanics are highly folded. In the western part of the Sub-Region the rocks of Cretaceous age are primarily unconsolidated sand and clay beds overlying shales and sandstones.

Ground water occurs in the eastern and central parts in openings of bed rock associated with major faults and folded rocks, and in the southwestern part of the Sub-Region it occurs in the intergranular pore space in the Cretaceous sandbeds.

The ground-water discharge at about 90 percent streamflow duration is between 50 and 100 thousand gpd per square mile in the northwestern and southern parts and less than 50 thousand gpd per square mile in the west-central part of the Sub-Region. The discharge is between 100 and 300 thousand gpd per square mile in the southeastern and western parts and more than 300 thousand gpd per square mile in the east-central part of the Sub-Region. Individual wells properly located and constructed will yield more than 600 gpm in the northeast and southwest parts of the Sub-Region. The wells will yield between 300 and 600 gpm in the central part and between 100 and 300 gpm in the eastern and west-central parts of the Sub-Region. The average depths of high yield wells are greater than 500 feet below land surface in the north-central part of the Sub-Region, between 250 and 500 feet below land surface throughout most of the Sub-Region and between 125 and 250 feet below land surface in the west-central part.

A well field capable of producing 1 mgd would cost between 4 and 25 thousand dollars to construct throughout most of the Sub-Region except in the southeastern part where it is between 25 and 100 thousand dollars and in the north-central part where the cost would be more than 100 thousand dollars. The cost of producing ground water based upon 1 mgd and including pumping costs, construction costs, and interest for a 25-year period on construction costs for raw water delivered at the well head would be less than $0.05 or between $0.05 and $0.25 per thousand gallons throughout most of the Sub-Region except in the southeastern part where it would be between $0.25 and $0.75 per thousand gallons and the west-central part where the cost would be more than $0.75 per thousand gallons.

The optimum development of ground water at these costs would be less than 25 thousand gpd per square mile in the west-central part, between 25 and 250 thousand gpd per square mile in the northwestern part, between 250 and 500 thousand gpd per square mile in the southeastern and western parts, and more than 500 thousand gpd per square mile in the east-central part of the Sub-Region.

PART III

SELECTED WATER-SUPPLY STUDY AREAS

The water-supply study areas in this part of the report were those for which the U. S. Geological Survey received requests for information on ground-water supplies from other agencies participating in the Appalachian Studies. For the most part, the requests came from the District Offices of the Corps of Engineers, the Office of Appalachian Studies, or the Federal Water Pollution Control Administration.

The descriptions of the study areas were mainly based upon existing reports in accordance with the original agreement between the Corps of Engineers and the Geological Survey. In three areas the local District Offices of the Geological Survey were requested to prepare the area reports. They were the Greenbrier area, the North Mountain area, and the Clinchfield area. The authors are indicated on these area reports.

The locations of the ground-water supply study areas are shown in Figure 10. In the text the reporting order is generally from north to south.

JAMESTOWN-CASSADAGA CREEK AREA

The Jamestown-Cassadaga Creek Area is in the Appalachian Plateaus physiographic province in the southwestern part of New York State. Both Jamestown and Cassadaga Creek are in Chautauqua County.

The area is underlain by bedrock of Devonian age. The rocks are principally shale but contain interbedded sandstone and conglomerate. Crain (1966) reports that the depth to Devonian rock ranges from about 25 feet below land surface in the upland areas to about 200 to 600 feet below land surface in the valleys. The Devonian rocks are overlain by unconsolidated Quaternary deposits of gravel, sand, silt and clay that are mainly of glacial origin. The sediments are unsorted over most of the area where they occur as till deposits. In the valleys, however, the deposits are generally well sorted by stream action and occur in thick beds. Crain (1966) gives numerous sections and logs in the vicinity of Jamestown and along Cassadaga Creek Valley which show the depth, thickness and extent of the clay, sand, and gravel beds.

Ground water occurs in the bedrock units and in the unconsolidated deposits. Wells tapping bedrock are not as productive as those tapping the coarse sand and gravel deposits of the unconsolidated sediments in this area.

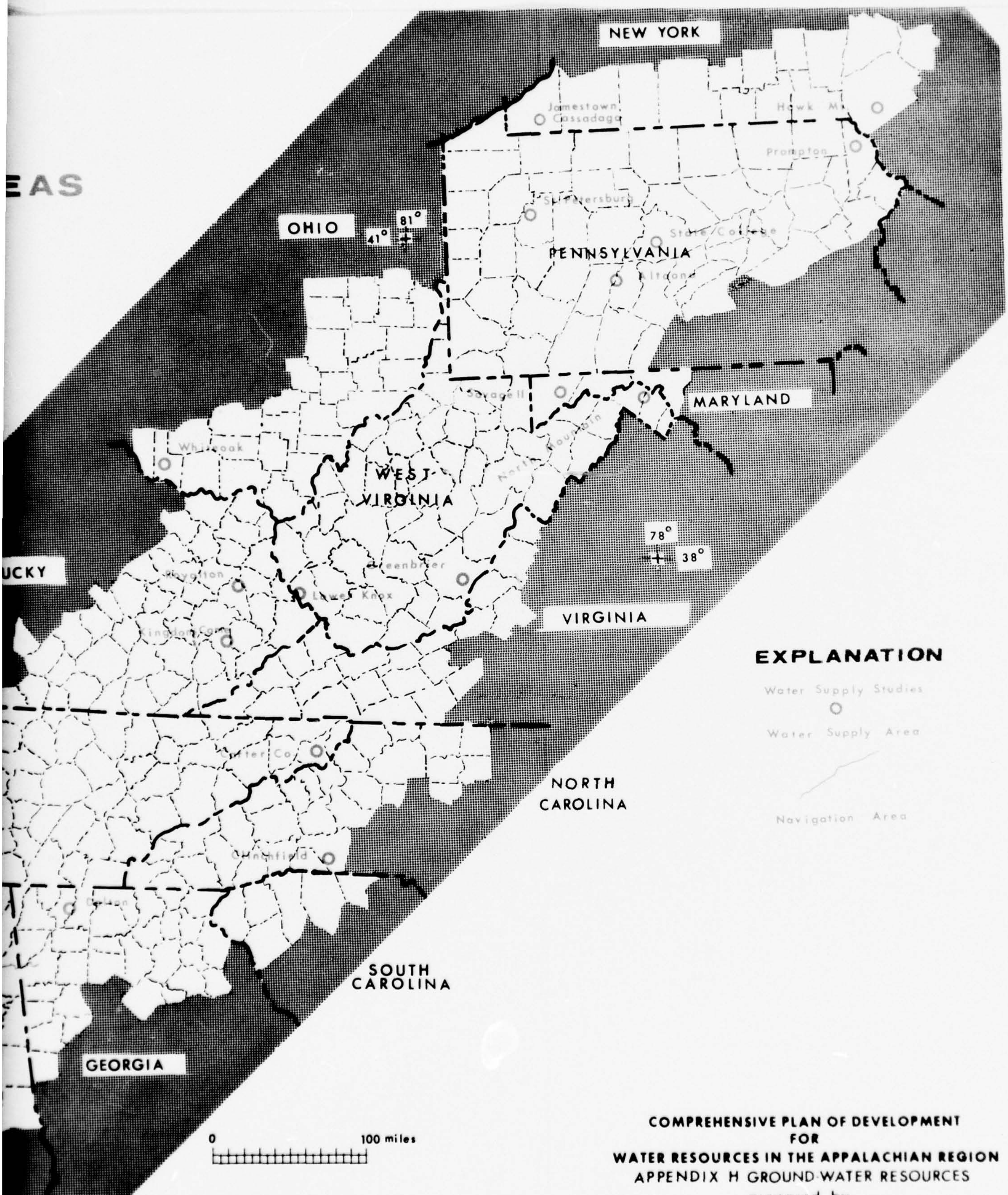
In bedrock, ground water occurs in joints which have been enlarged near land surface by weathering. The intergranular pore space of bedrock contributes little water to wells as it has been distorted and diminished by the compaction and induration of the rocks. Most of the water from wells tapping bedrock is derived from fractures in the rock. As there are no major fault zones and no warping or folding of rock in the area, most rock fractures result from jointing. The joints have been enlarged by weathering near land surface. With increase in depth below land surface there is a decrease in the amount of enlargement from weathering of the fractures. Wells tapping bedrock generally yield less than 5 gpm although one well near Jamestown is reported to yield about 30 gpm on a sustained basis.

Wells screened in the sand and gravel beds along the Cassadaga Creek valley (Fig. 11) will yield more than 250 gpm on a sustained basis. According to Crain (1966), the amount of water available from the principal aquifer, which he termed the "Jamestown Aquifer", is dependent upon recharge to the aquifer from surface sources. He suggested surface storage which would increase the amount of available water for recharge during dry seasons.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.04 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.04 per thousand gallons) is calculated at about 150 thousand gpd per square mile. Surface storage would alter present conditions and allow for recharge to the aquifer through deltaic deposits and by infiltration. The suggested surface storage could be utilized in two ways. The first would be a series of small reservoirs in the tributaries along the northeast side of Cassadaga Creek which would serve to impound runoff during wet periods and augment the flow of the tributaries across deltaic deposits during dry periods. The low-flow augmentation would allow for a greater rate of recharge from the tributaries than is now occuring. The second is the increase in the amount of water available for infiltration from surface sources to well fields during normally low-flow periods by low-flow augmentation.

LOCATION OF STUDY AREAS

Figure 10 – Location of Study Areas



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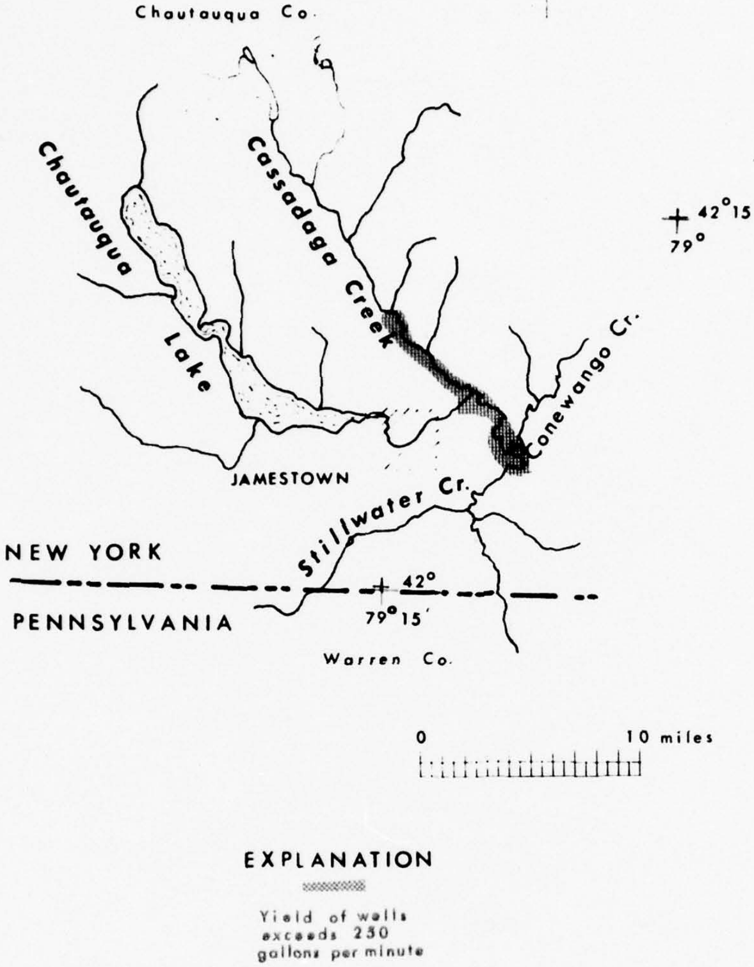

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Figure 11. The Jamestown Cassadaga Creek Area

It is not suggested that the recharge areas be inundated by reservoirs because silt sediment in the reservoirs would tend to reduce the permeability of the rock materials of the recharge areas.

The chemical quality of ground water from Cassadaga Creek Valley near Jamestown is generally acceptable for municipal use without extensive treatment. Ground water from Stillwater Creek, south of Jamestown, contains chlorides in excess of the amount recommended by the U. S. Public Health Service.

Selected Reference

Crain, Leslie J., 1966, Ground-water resources of the Jamestown area, New York: New York Dept. Conserv., Water Resources Commission Bull. 58, 167 p.

HAWK MOUNTAIN RESERVOIR AREA

The Hawk Mountain Reservoir area is in the Appalachian Plateaus physiographic province in Delaware County, New York. The area is underlain by rocks of Late Devonian age that are mainly sandstone, siltstone, and shale. A thin mantle of glacial till covers most of land surface and thick glacial outwash deposits are common in the valleys. Ground water occurs in the fracture zones of bedrock and in the intergranular pore spaces of the coarse, sorted glacial-alluvium deposits of the valleys.

The oldest rocks that outcrop in the area are of Late Devonian age. These include rocks of several units that are not separated into groups or formations in this report because they have similar hydrologic characteristics. The Devonian rocks are slightly folded and the East Branch of the Delaware River flows along the axis of an eroded anticline. Thus, the rocks dip gently away from the river to the northwest and southeast. The folding and jointing of the rocks has produced fractures which increase the capacity of the rocks to yield ground water. Wells that tap fracture zones in the bedrock units will yield as much as 100 gpm in the vicinity of Hancock.

Unconsolidated deposits of sand, gravel, silt, and clay occur from Hancock to Downsville Dam in the East Branch valley. In the vicinity of Hancock the deposits extend to depths of more than 200 feet below land surface. The deposits thin in an upstream direction from Hancock toward Downsville where they are about 75 feet thick. A section (Soren, 1963) indicated more than 100 feet of well sorted sediments in the valley about 4 miles upstream from Hancock.

Wells tapping the coarse sand and gravel beds in this area yield more than 100 gpm. The section indicated that the stratified, coarse sediments are hydrologically connected with the river and it is probable that considerably higher yields could be developed from wells near Hancock. At similar places in the county, wells do produce more than 1000 gpm from coarse valley fill that is hydrologically connected to streams.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.02 per thousand gallons for raw water delivered at the well head near Hancock (Fig. 12). Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at $3\frac{1}{4}$ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.02 per thousand gallons) is calculated at about 490 thousand gpd per square mile.

The chemical quality of water from the unconsolidated sediments in this area is generally acceptable for most uses. The pH of water ranges from about 6.5 to 7.0. The total dissolved solids average about 35 ppm (parts per million) and chloride content and dissolved iron content are below the maximum recommended by the U. S. Public Health Service.

Selected References

Geologic Map of New York, 1961: New York Geol. Survey, Albany Map and Chart Series 5.

Soren, Julian, 1963, The ground-water resources of Delaware County, New York: New York Water Resources Comm. Bull. GW-50, 59 p.

PROMPTON RESERVOIR AREA

The Prompton Reservoir area is in the Appalachian Plateaus province in Wayne County in northeastern Pennsylvania. The area is underlain by rocks of Devonian age that are mantled by glacial drift. In the stream valleys deposits of well sorted glacial outwash are common. Ground water occurs in the fracture zones in the bedrock units and in the intergranular pore space of the well sorted glacial-alluvium deposits.

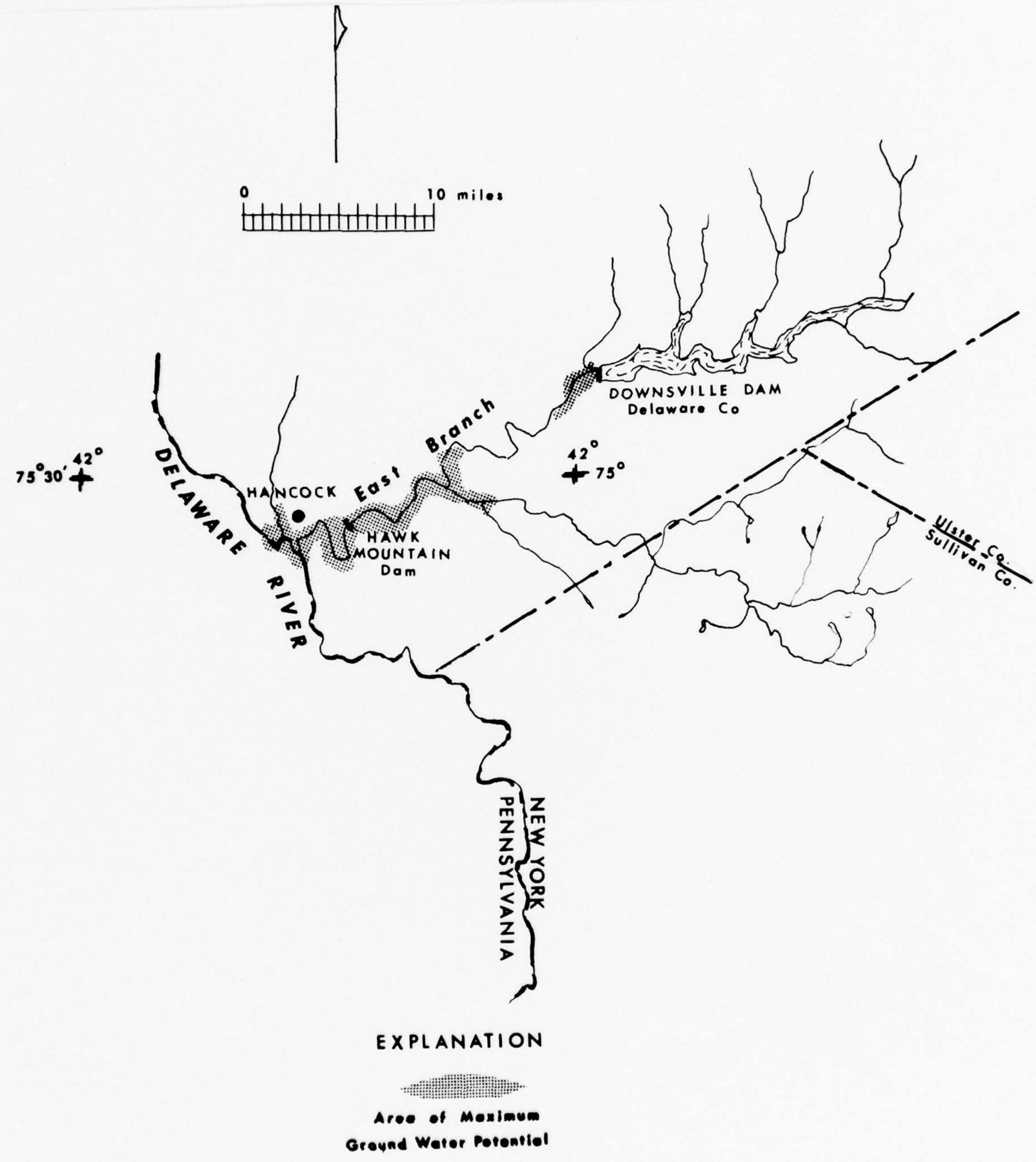

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Figure 12. The Hawk Mountain Area

The Devonian rocks that underlie the area are mainly shale with interbedded sandstone and conglomerate. The rocks are essentially flat-lying in the area of study although they border a major syncline along the western edge of Wayne County. The dip of the strata resulting from the syncline flattens rapidly toward Prompton Reservoir. Most of the fractures in bedrock near Prompton result from jointing rather than folding associated with the syncline. Ground water occurs in the bedrock units in both intergranular pore space and fractures of the sandstone and in the fracture zones of the shale. Wells tapping fractures in the sandstone beds will produce as much as 60 gpm on a sustained basis. Wells tapping the shale units yield less than 10 gpm but are generally adequate for domestic use.

The Devonian basement rocks are covered throughout most of the area by glacial deposits. The major Pleistocene glaciers extended south of the Prompton area, and in retreating deposited till over most of the area. In places the till has eroded leaving basement rock exposed at the surface. The eroded till material was transported by streams, sorted, and redeposited in some of the stream valleys. Near Prompton Reservoir deposits of sorted and stratified glacial material are reported to be as much as 160 feet thick in the valleys. Wells tapping the coarse sand and gravel deposits in the area will produce more than 100 gpm. The coarse sand and gravel beds are limited in areal extent and function more to transmit water from streams to wells than as major reservoirs for the storage of vast quantities of ground water. For this reason, low-flow augmentation of streamflow would increase the available ground water from the glacial-alluvium deposits.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.04 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.04 per thousand gallons) is calculated at about 160 thousand gpd per square mile.

The chemical quality of water from the glacial-alluvium deposits is generally acceptable for most uses without extensive treatment. Analyses indicate an average of about 90 ppm of total dissolved solids in waters from the glacial-alluvium deposits.

The same waters have an average content of 3 ppm of chloride, 62 ppm total hardness, and 8 ppm sulfate.

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Pennsylvania Department of Internal Affairs, Topographic and Geologic Survey, 1960, Geologic map of Pennsylvania (scale 1:250,000).

Lohman, Stanley W., 1937, Ground water in northeastern Pennsylvania, with analyses by Margaret D. Foster, L. A. Shinn, and K. T. Williams: Pennsylvania Geol. Survey, 4th ser., Bull. W-4, 312 p.

ST. PETERSBURG AREA

The St. Petersburg area is in the Appalachian Plateaus province in western Pennsylvania. The area is underlain by rocks of Pennsylvanian and Mississippian ages. Ground water occurs in the Pennsylvanian and Mississippian bedrock units and in alluvium deposits along the Allegheny River valley.

The oldest rocks that outcrop in the area are massive conglomerates, sandstone, and shales of the Pocono Sandstone of Mississippian age. These rocks occur in the valley floor of the Clarion River where the river has cut down through the overlying Pennsylvanian rocks. Wells that tap clean sandstone units of the Mississippian rocks are generally the most productive in the area. The yield of these wells ranges up to about 110 gpm and the water required little or no treatment for most uses.

The Mississippian rocks are overlain by rocks of Pennsylvanian age that are divided into two formations. The lower of these is the Pottsville Formation which is generally massive sandstone containing beds of shale, conglomerate, and coal. The sandstone units will yield 20 to 40 gpm to wells but the water frequently contains excessive concentrations of dissolved iron and requires treatment for most uses. The rocks that overlay the Pottsville Formation are in the Allegheny Formation, also of Pennsylvanian age. The Allegheny Formation is primarily sandstone but contains shale, limestone, and coal beds. The sandstone units have about the same hydrologic characteristics in the Allegheny Formation as in the Pottsville Formation.

Alluvium deposits occur as thin layers of sand, gravel, and silt in the Clarion River valley. The deposits are not thick enough or of sufficient areal extent to be considered an aquifer in this area.

Alluvium deposits of glacial origin occur in the Allegheny River valley near the confluence of the Clarion and Allegheny Rivers. Wells tapping the course sand beds of these deposits are reported to yield as much as 250 gpm. The distance from the Allegheny valley to the vicinity of St. Petersburg makes it seem impractical to develop ground-water supplies for St. Petersburg in the Allegheny valley.

Ground-water supplies can be developed in the Clarion valley near St. Petersburg (Fig. 13). On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.17 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.17 per thousand gallons) is calculated at about 200 thousand gpd per square mile.

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Leggette, R. M., 1936, Ground water in northwestern Pennsylvania, with analyses by Margaret D. Foster, W. L. Lamar, and S. K. Love: Pennsylvania Geol. Survey, 4th ser., Bull. W-3, 215 p.

Pennsylvania Department of Internal Affairs, Topographic and Geologic Survey, 1960, Geologic Map of Pennsylvania (scale 1:250,000).

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STATE COLLEGE AREA

The State College area is in the Valley and Ridge province about 5 miles east of the Appalachian Plateaus province, in Centre County, Pennsylvania. Most of the area is underlain by rocks of Ordovician age. Ground water occurs in fracture zones and in fractures enlarged by solution channels in the bedrock units.

The Ordovician rocks that underlie the area are mainly massive limestone and dolomite beds. The rocks are crystalline and have low permeability except where solution channels have formed along joint fractures. State College is near the east flank of an anticline that trends northeast-southwest. The older rocks exposed near the axis of the anticline are limestone and dolomite of Ordovician and Cambrian age. About 3 miles southeast and about 5 miles northwest of State College younger rocks of Silurian age outcrop along the flanks of the anticline. The Silurian rocks are mainly sandstone and quartzite. The sandstone and quartzite units are resistant to erosion and form high land along the edges of the valley formed by the more easily eroded limestone and dolomite units.

The State College area is about 30 miles south of the southern extent of glaciation and streams in the area flow toward the glaciated region; therefore, there are no glacial-alluvium deposits in the stream valleys near State College. Other alluvium deposits are so thin and limited in areal extent that they are not considered aquifers in this area.

Ground water may be produced in quantity from fractures and solution channels in the bedrock. Wells that tap openings in bedrock will produce more than 520 gpm, wells that do not intersect fractures or channels yield little water.

Thus, the success of constructing high-yield wells depends entirely upon location of the wells so that they tap major fracture or solution openings in bedrock. Most of the wells in the area that yield more than 200 gpm are located one to two miles north or northwest of State College. These locations would place the wells near the axis of the anticline where fracturing of bedrock and the resulting development of solution channels would be greatest.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.06 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.06 per thousand gallons) is calculated at about 110 thousand gpd per square mile.

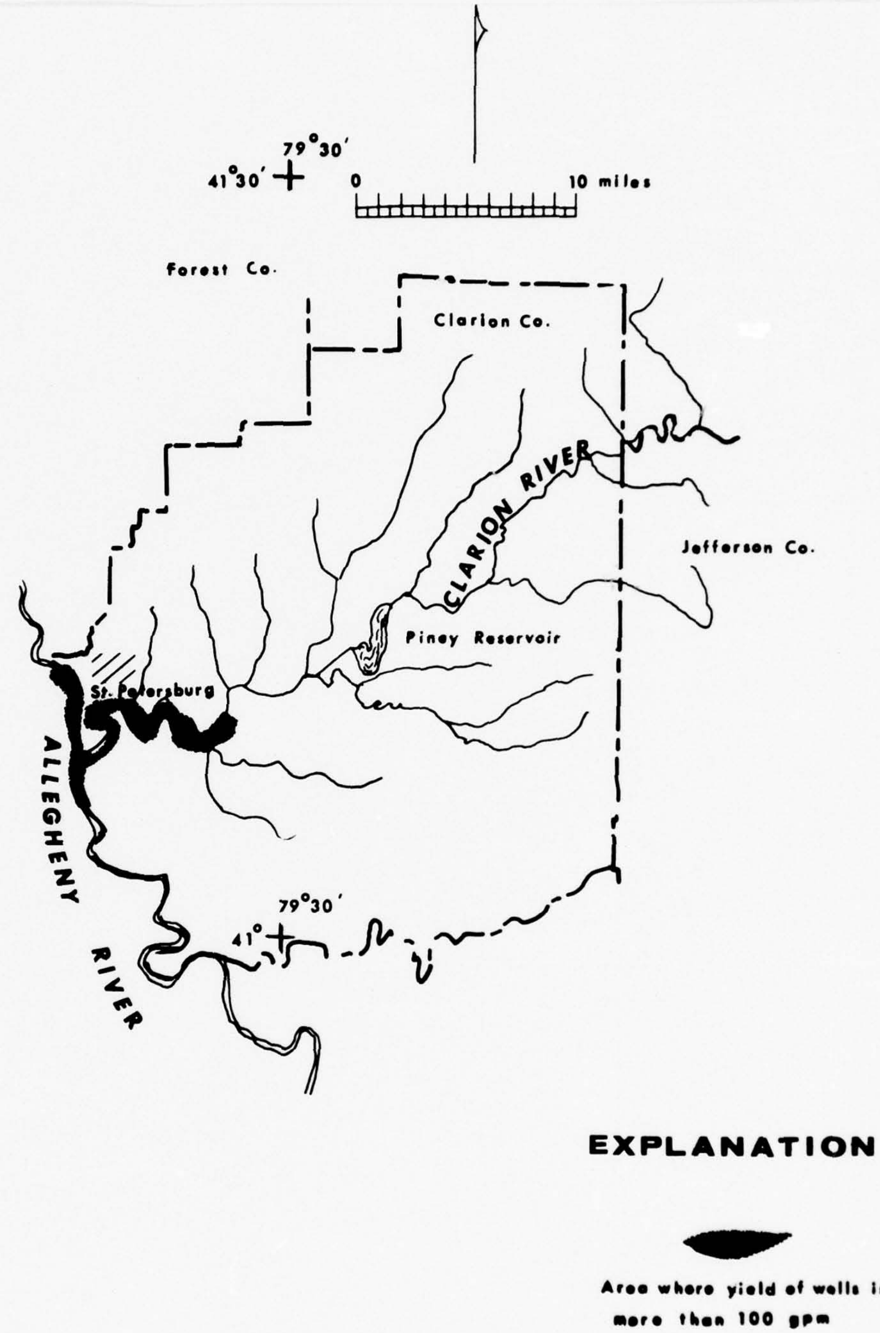

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Figure 13. The St. Petersburg Area

The chemical quality of ground water from a well at State College, tapping dolomite basement rocks is generally acceptable, with treatment, for most uses. The water would require treatment for hardness which is about 250 ppm. The dissolved iron content is less than 0.1 ppm and the chloride content less than 10 ppm.

Selected References

Pennsylvania Department of Internal Affairs, Topographic and Geologic Survey, 1960, Geologic map of Pennsylvania (scale 1:250,000).

Lohman, Stanley W., 1938, Ground water in south-central Pennsylvania, with analyses by E. W. Lohr: Pennsylvania Geol. Survey, 4th ser., Bull. W-5, 315 p.

ALTOONA AREA

The Altoona area is in the Valley and Ridge province in Blair County, Pennsylvania. The area is near the west edge of the province, about 3 miles east of the Appalachian Plateaus province. The underlying rocks range from Ordovician to Devonian in age. Altoona is on the western side of the axis of an anticline and the rocks dip steeply, nearly vertical, to the northwest. Ground water occurs in the fracture zones and in solution channels in the bedrock units.

Rocks of Ordovician age outcrop between 3 and 4 miles east of Altoona and dip under the city. Where these rocks outcrop they are near the axis of the anticline and dip slightly; in a westward direction from the outcrop, the dip increases steeply and the Ordovician rocks are overlain by younger rocks. The Ordovician rocks are sandstone with interbedded shale. The sandstone is, for the most part, a dense quartzite with, generally, low intergranular pore-space permeability. Ground water occurs in the fracture zones and wells that tap Ordovician rocks (Fig. 14, Zone A) will yield between 20 and 60 gpm. Because of the generally low yield of wells and the distance from Altoona, Zone A may not be an economical aquifer for municipal supply in Altoona.

Silurian rocks overlie the Ordovician rocks and outcrop in a band along the eastern side of Altoona (Fig. 14, Zone B). The lower units of Silurian age are predominantly sandstone with interbedded shale and the upper units are predominantly shale and siltstone with interbedded sandstone and limestone. Ground water occurs mainly in fracture zones in the rocks of Silurian age. Wells tapping these rocks will yield between 30 and 150 gpm.

Devonian rocks outcrop in most of the city of Altoona and for several miles west, in a band about four miles wide that trends northeast-southwest. The rocks are mainly interbedded shale, limestone, and sandstone. The lower units are primarily shale with interbedded sandstone (Fig. 14, Zone C). The upper units are sandstone with interbedded shale (Fig. 14, Zone D). Wells tapping Devonian rocks of Zone C will yield between 20 and 100 gpm and wells tapping Zone D will yield between 35 and 500 gpm.

A unit classified as Devonian and Silurian rocks outcrops at the southeast corner of Altoona (Fig. 14, Zone E). This unit is predominantly limestone. The fracture zones in the rocks have been enlarged by solution of the limestone, increasing the capacity of the rock to yield water to wells. Wells tapping fracture zones in the limestone will yield between 50 and 1000 gpm.

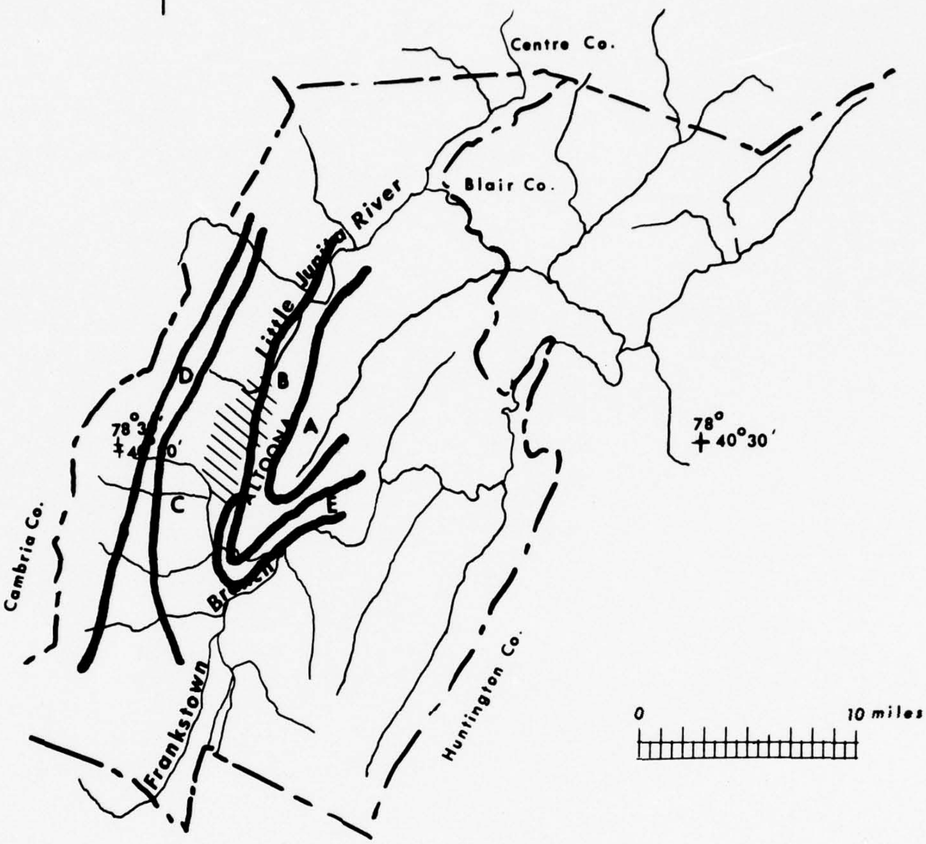
On the basis of the assumptions explained and delimited in Part I of this report, the costs of producing ground water in each zone, per thousand gallons for raw water delivered at the well head are listed below. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at $3\frac{1}{4}$ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpost, competent professional assistance should be obtained. The costs per zone are:

Zone B $0.09 per thousand gallons
Zone C $0.16 per thousand gallons
Zone D $0.07 per thousand gallons
Zone E $0.05 per thousand gallons

Selected References

Pennsylvania Department of Internal Affairs, Topographic and Geologic Survey, 1960, Geologic map of Pennsylvania (scale 1:250,000).

Seaber, P. R., and Hollyday, E. F., 1965, An appraisal of the ground-water resources of the Juniata River basin: U. S. Geol. Survey open-file rept., 58 p.



EXPLANATION

Range of Yields of Wells

Zone	Yield in gallons per minute
A	20 - 60
B	30 - 150
C	20 - 100
D	35 - 500
E	50 - 1000

Figure 14. The Altoona Area

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SAVAGE II RESERVOIR AREA

by

Este F. Hollyday [1]

Savage II reservoir site is in the eastern part of Garrett County, Maryland. The site is approximately 7 miles northwest of the adjacent towns of Luke and Westernport, Maryland, and Piedmont, West Virginia (Fig. 15). The proposed reservoir is planned to provide supplemental water storage for the existing Savage River Reservoir, upstream from these towns.

The drainage basin of Savage River is entirely within the Allegheny Mountain section of the Appalachian Plateaus province. This section is characteristically a mature plateau of strong relief. The plateau is traversed from southwest to northeast by several mountains that have been formed by the erosion of open folds. The entire area of study is underlain by predominantly clastic sedimentary rocks that range from Devonian through Pennsylvanian in age.

Three broad folds traverse the area of study. The towns of Luke, Piedmont, Westernport, and Frostburg are situated near the axis of the Georges Creek-Upper Potomac synclinal basin. The Savage River flows along the eastern margin of the Deer Park anticline. The Castleman synclinal basin is adjacent to the western margin of the Deer Park anticline. Within the area of study, rocks exposed in synclinal basins yield larger quantities of water to wells than rocks exposed in anticlines. No major faults are known in the area of study.

Ground water occurs under both artesian and non-artesian conditions in the area of study. Water encountered by wells less than 100 feet deep, generally, is under non-artesian conditions everywhere. Water encountered by wells more than 300 feet deep, generally, is under artesian conditions in synclinal basins. Water under artesian conditions commonly rises to within 30 feet of land surface and in some cases flows. The most productive wells derive water from sandstone beds, where the water occurs and moves predominantly in fractures and fissures.

1. Geologist, U. S. Geological Survey, Towson, Maryland

The rocks of the area may be divided into two units on the basis of the yield of water wells and the dissolved solids composition of the water they contain. Unit 1 exposed in synclinal basins, is comprised of the Pocono Sandstone, Pottsville Formation, Allegheny Formation, and Conemaugh Formation. Sixty wells drilled in unit 1 have yields ranging from 1 to 433 gpm, and averaging 13 gpm. These wells have depths ranging from 22 to 1,350 feet and averaging 80 feet. A few wells about 500 feet deep yield 300 gpm. Although the average yield of wells in unit 1 is 13 gpm, an analysis of specific-capacity data from these wells indicated that this unit is potentially capable of much larger yields. Based upon an analysis of specific-capacity data, about 50 percent of the wells designed for maximum yield may be expected to yield more than 100 gpm.

Analyses of samples of well water from unit 1 indicate a calcium-magnesium-sulfate water composition that would present few problems for most water uses. The water from all wells sampled has a hardness expressed as concentration of calcium carbonate ranging from 20 to 560 ppm and averaging about 110 ppm. The water has a total iron concentration ranging from less than 0.1 to 88 ppm and averaging 0.3 ppm. The average concentration of iron in water from unit 1 indicated that water from about half the wells may have to be treated for iron removal before use in a municipal supply. Wells greater than 700 feet deep commonly yield water with a salty taste.

Unit 2, exposed in the anticline, is comprised of the Jennings, Hampshire, Greenbrier, and Mauch Chunk Formations. Seventy wells drilled in unit 2 have yields ranging from 1 to 180 gpm and averaging 13 gpm. These wells have depths ranging from 40 to 314 feet and averaging 90 feet. Based upon an analysis of specific-capacity data, about 50 percent of wells designed for maximum yield may be expected to yield more than 60 gpm.

Analyses of samples of well water from unit 2 indicate a calcium-magnesium-bicarbonate water composition that would be suitable for most uses. The water from wells has a hardness ranging from 19 to 240 ppm and averaging about 70 ppm. The water has a total iron concentration ranging from less than 0.1 to 12 ppm and averaging 0.1 ppm.

A quantity of ground water sufficient for commercial or limited municipal supply may be developed from well fields immediately north of Westernport along Georges Creek valley.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water from Unit I would be $0.30 per thousand gallons for raw water delivered at the well head.

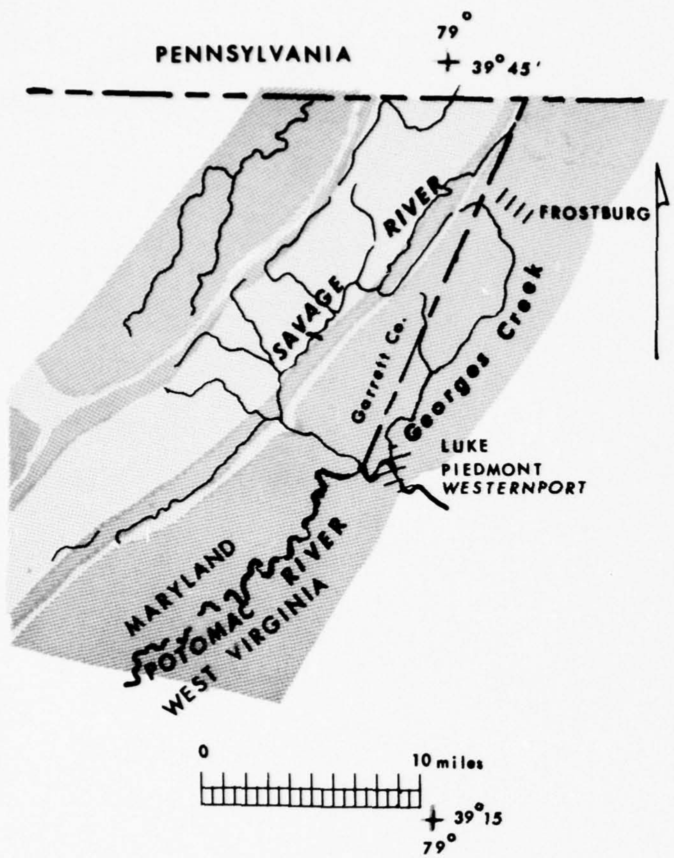

Figure 15. The Savage II Reservoir Area

EXPLANATION

Unit 1

Sandstone and shale; some coal. Average potential yield to wells, 100 gpm. Calcium-magnesium-sulfate water. Includes Pocono ss., Pottsville Fm., Allegheny Fm., and Conemaugh Fm.

Unit 2

Shale and sandstone. Average potential yield to wells, 60 gpm. Calcium-magnesium-bicarbonate water. Includes Jennings Fm., Hampshire Fm., Greenbrier Fm., and Mauch Chunk Fm.

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Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.30 per thousand gallons) is calculated at about 80 thousand gpd per square mile.

Selected References

Amsden, T. W., Overbeck, R. M., and Martin, O. R., 1954, Geology and water resources of Garrett County: Maryland Dept. Geol. Mines and Water Resources Bull. 13, 349 p.

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WHITEOAK CREEK AREA

The Whiteoak Creek area, Brown County, Ohio is in the Central Lowland province. The area is underlain by unstratified deposits of gravel, sand, clay, and silt of glacial origin. The glacial deposits overlay bedrock of Ordovician age, which is primarily shale but is interbedded with thin limestone beds. The water-supply problems of the area deal with proposed residential, commercial, recreational, and industrial development in the central part of the county (Fig. 16).

Ground water occurs in the intergranular pore space in the unconsolidated deposits and in fractures in bedrock. The unconsolidated deposits are neither sorted nor stratified by particle size. Sand, clay, silt, and gravel are mixed so that the pore space normally filled with water in well-sorted sand or gravel layers is, here, partially filled with clay and silt. This reduces the capacity of the unconsolidated deposits to store and readily transmit ground water. Wells tapping the unconsolidated deposits generally yield 1 to 5 gpm in this area. Alluvial deposits in the White Oak stream valley are not of sufficient thickness or areal extent to constitute an aquifer capable of supplying large industrial or municipal water supplies.

Ground water occurs in the fracture zones of the bedrock units. In general, the shale and limestone units are dense and little ground water is available to wells from intergranular pore space. Wells tapping bedrock draw water from the fractures in the rock. The fractures in this area result from jointing and bedding in the rock. There are no major fault zones here which would tend to increase the amount of bedrock fracturing. The yield of wells tapping bedrock is less than 10 gpm in this area.

Ground-water discharge to the stream at about 90 percent streamflow duration is 7,700 gpd per square mile of drainage area. This is extremely low in comparision with most of the Appalachian Region and indicates the low storage characteristic of the rocks in the area. On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $.77 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH and that construction costs would be depreciated over a 25-year period with interest at $3\frac{1}{4}$ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $.77 per thousand gallons) is calculated at about 3 thousand gpd per square mile. It is unlikely that large industrial or municipal water supplies could be developed from ground-water sources at a cost competitive with surface-water sources in the area of development.

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Walker, Eugene H., 1957, The deep channel and alluvial deposits of the Ohio Valley in Kentucky: U. S. Geol. Survey Water-Supply Paper 1411, 25 p.

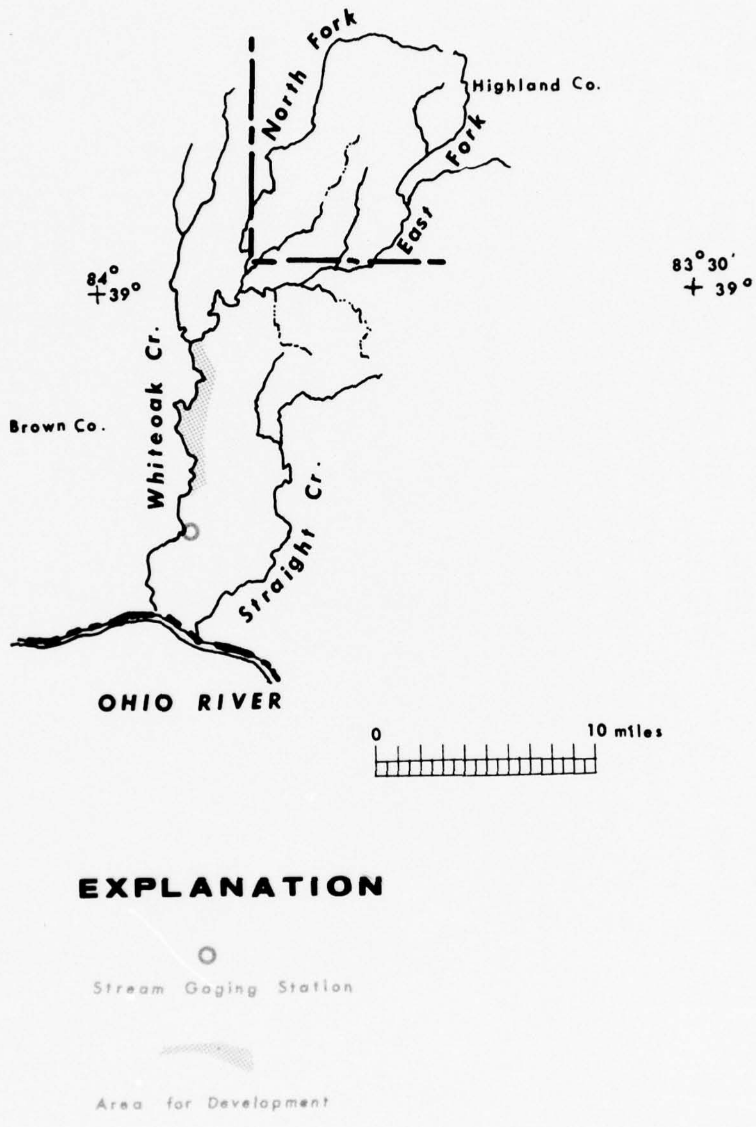

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Figure 16. The Whiteoak Creek Area

NORTH MOUNTAIN RESERVOIR AREA

The North Mountain Reservoir area, Berkeley County, is in the Valley and Ridge province in northeastern West Virginia. The area is underlain by rocks that range from Cambrian through Mississippian in age. Ground water occurs in abundance in fracture zones of limestone and shale and to a lesser extent in the intergranular pore space in sandstone units.

The rocks that underlie Berkeley County are highly folded. North Mountain is resistant Silurian rocks on the upthrown side of a major fault that separates two major synclines. To the west of North Mountain the rocks range from Devonian to Mississippian in age and dip to the northwest. East of North Mountain the rocks dip to the southeast in a syncline having its axis along Opequon Creek. The rocks east of North Mountain range from Cambrian through Ordovician in age. As this report deals with potential water supply for the city of Martinsburg, it will describe ground-water occurrence between North Mountain and Opequon Creek.

The oldest rocks in the area outcrop along a major fault on the southeastern side of North Mountain. The rocks are limestone of Cambrian age. This limestone is a dense, crystalline rock with thin interbedded sandstone units. As the limestone is crystalline and intergranular pore space is virtually nonexistent, ground water occurs mainly in fracture zones. Folding and faulting have sheared the limestone units and created fractures that allow the movement of ground water. Where ground water enlarged the fractures by dissolving rock adjacent to the fracture, the limestone units have become highly productive aquifers. The Ordovician rocks that overlie the Cambrian rocks are also limestone and ground water occurs under similar conditions in both the Cambrian and Ordovician limestone. The broad band of maximum ground-water potential along the western side of Martinsburg (Fig. 17) includes both Cambrian and Ordovician limestone. The narrow band east of Opequon Creek includes only Ordovician limestone. Wells tapping fracture zones in these two areas will yield as much as 1000 gpm. The average yield of wells designed for municipal or industrial use is about 650 gpm.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.06 per thousand gallons for raw water delivered at the well head.

Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.06 per thousand gallons) is calculated at about 40 thousand gpd per square mile.

Selected Reference

Bieber, Paul P., 1961, Ground-water features of Berkeley and Jefferson Counties, West Virginia: West Virginia Geol. Survey Bull. 21, 31 p.

THE GREENBRIER RESERVOIR AREA [1]

The study area for the Greenbrier Reservoir system is limited to the vicinity of Reservoir 40 and deals primarily with water supply for White Sulphur Springs. The study area includes about 250 square miles in the east-central part of Greenbrier County, West Virginia (Fig. 18). It is in the Valley and Ridge province and is underlain by rocks that range from Silurian to Mississippian in age. Ground water occurs mainly in solution channels developed along fractures in the limestone units and to a lesser extent in fractures in the shale units.

The oldest rocks that outcrop in the area are sedimentary rocks of Silurian age. These outcrop along the crest of an eroded anticline that trends northeast-southwest through the area, about two miles west of Alvon and White Sulphur Springs. The rocks are mainly sandstone and shale with interbedded limestone. No wells are reported to tap these rocks in this area.

Rocks of Devonian age outcrop along the eastern and western sides of the Silurian rocks and underlie Alvon and White Sulphur Springs (Fig. 18). These rocks include shale, sandstone and limestone. One limestone unit, the Helderberg, is the source of water for wells at White Sulphur Springs and of Alvon Springs. Ground water occurs in the Helderberg Limestone in fracture zones that have been enlarged by the development of solution channels.

1 Abstracted from unpublished data by P. W. Johnson, Hydrologist, U. S. Geological Survey, Charleston, West Virginia

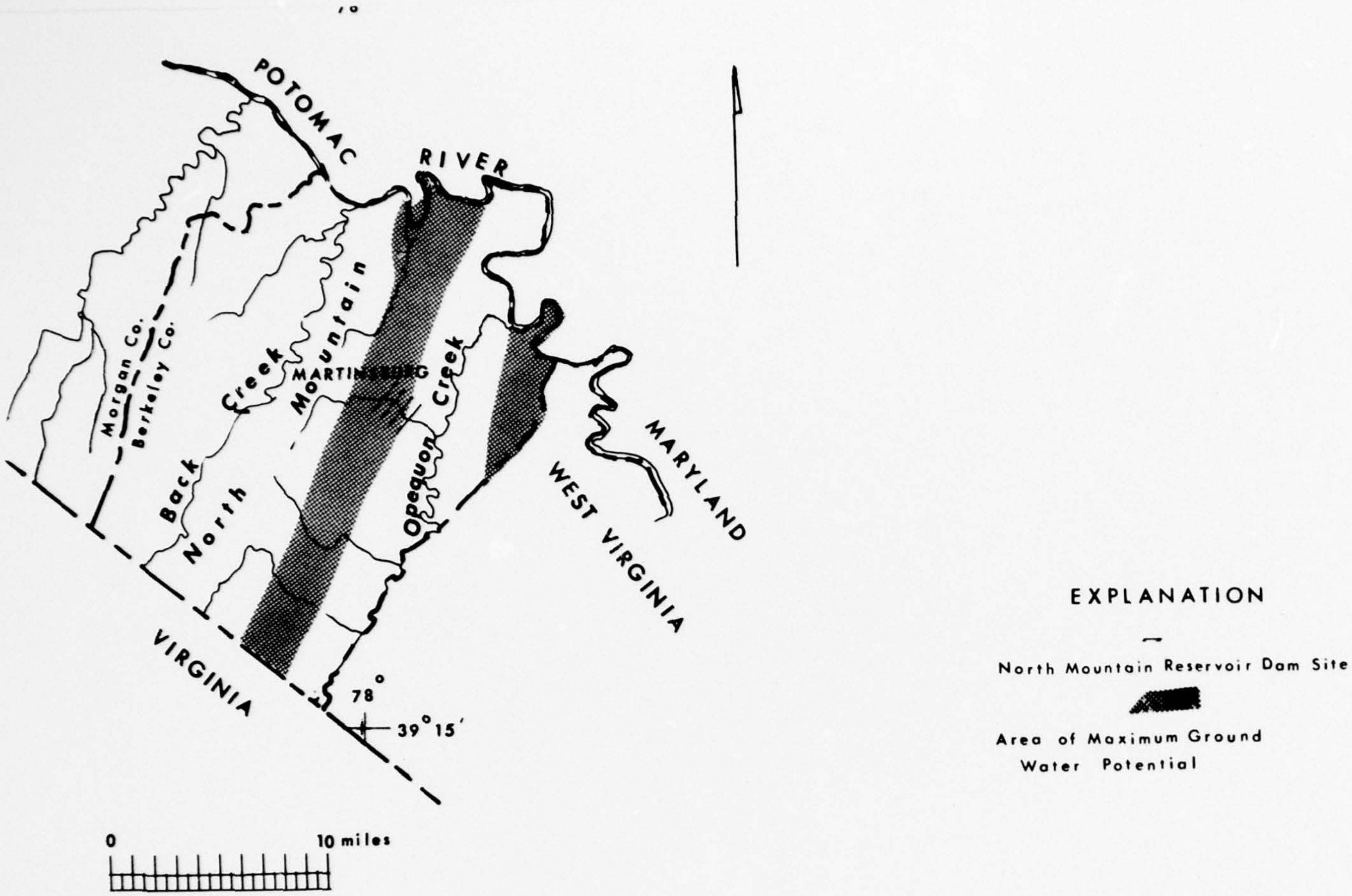

Figure 17. The North Mountain Area

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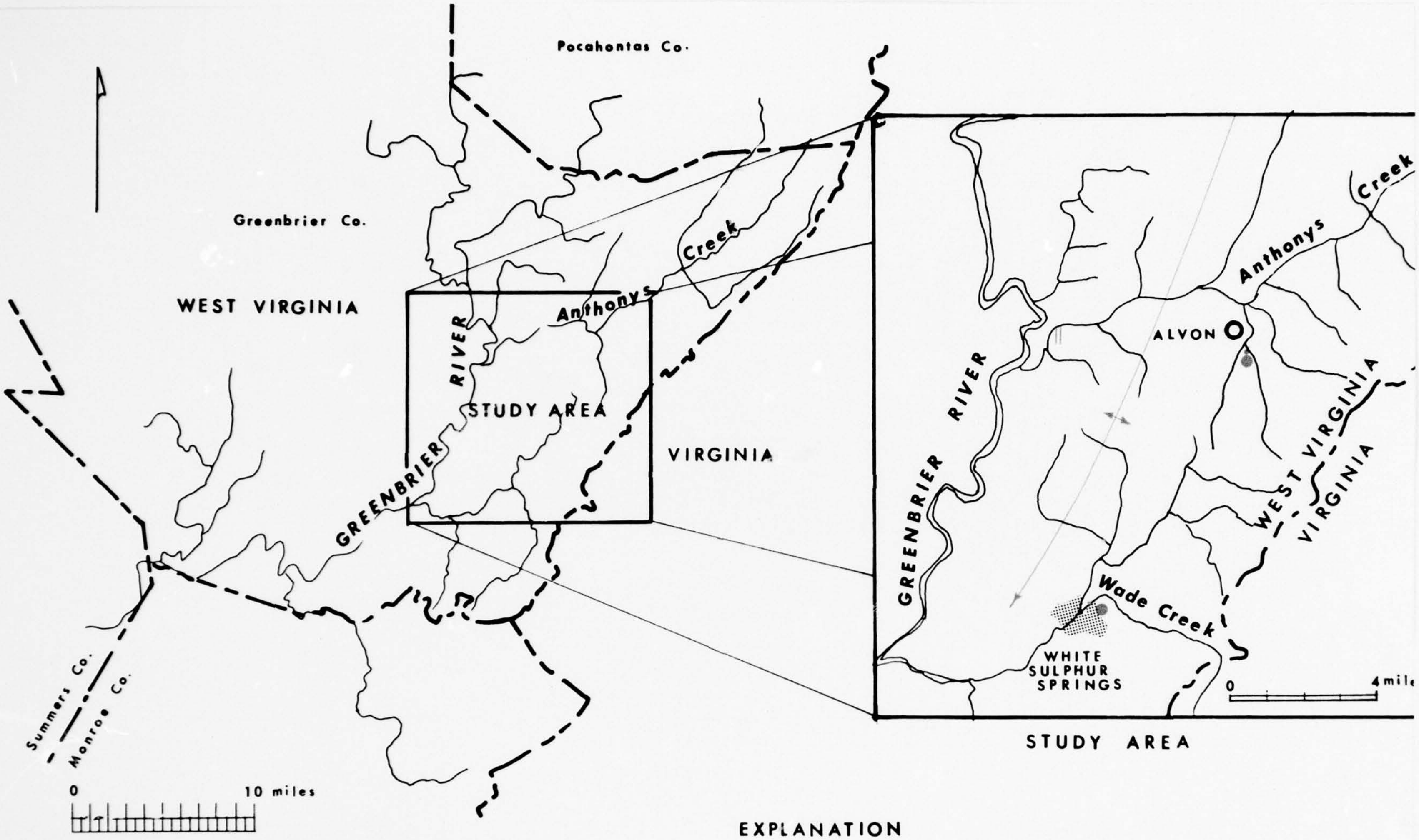

EXPLANATION

Spring

Well

Axis of Anticline

Reservoir 40 Dam Site

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Figure 18. The Greenbrier Reservoir Area

Water from this limestone generally has a high hardness content but is otherwise less mineralized than water from the Marcellus Shale, also of Devonian age. The highly mineralized springs in White Sulphur Springs derive their water from the Marcellus Shale.

Rocks of Mississippian age outcrop along the western side of the Devonian rocks and underlie the Greenbrier River. The basal unit is a sandstone unit which is overlain by a limestone unit. The Greenbrier River has entrenched itself into the easily eroded limestone unit and, in many places, has cut down to the more resistant sandstone unit. Wells in the area tapping the Mississippian rocks yield 20 to 30 gpm.

The principle known sources of ground water near White Sulphur Springs is the Helderberg limestone unit. Alvon Springs, about 9 miles northeast of White Sulphur Springs, derives its water from the Helderberg limestone. Alvon Springs is the present source of municipal supply for White Sulphur Springs. The measurments of discharge at Alvon Springs ranges from about 900 gpm to about 1400 gom. The fluctuations of ground-water levels in Devonian rocks in this area is about 3 feet. From this, it would appear that the specific capacity of Alvon Springs is about 170 gallons per foot of head. Thus, if the spring impoundments were raised 5 to 6 feet above present levels, it would be reasonable to expect the springs to stop flowing during dry periods. The quality of water from Alvon Springs is generally acceptable for most uses except that the water is slightly hard. The total hardness of the water is about 95 ppm.

A well at the Federal Fish Hatchery in White Sulphur Springs also taps the Helderberg Limestone. The well is 205 feet deep, cased to 164 feet below land surface and, reportedly, taps a solution channel between the depths of 184 and 187 feet. The specific capacity of the well is about 11 gallons per foot of drawdown. The chemical quality of water from the well is generally good except for hardness which is more than 400 ppm and the sulfate content which exceeds 300 ppm. Water from the aquifer at White Sulphur Springs would require treatment for municipal use.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.04 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained and an extensive test drilling program would be required.

TUG FORK AREA

Lower Knox is designed to control the headwaters of the Tug Fork. Tug Fork Basin is the drainage area of the Tug Fork of Big Sandy River. Tug Fork forms the boundary between West Virginia and Kentucky and, in places, Tug Fork is the boundary between West Virginia and Virginia. The Tug Fork Basin contains 1,557 square miles in three states; Kentucky, Virginia, and West Virginia.

The entire Tug Fork Basin is within the Kanawha section of the Appalachian Plateaus province (Fenneman, 1946). Land surface within the basin ranges from about 525 to more than 2200 feet above mean sea level. Valleys in the headwaters are steep sided and the terrain is irregular. Down stream the relief is less extreme. The entire basin is underlain by rock of sedimentary origin.

The sedimentary rocks underlying the basin are of Mississippian, Pennsylvanian, and Quarternary age. Outcrops of rocks of Mississippian age occur in the valley bottoms in McDowell County, West Virginia. The rocks are principally red shales containing a few interbedded sandstone beds. Two Pennsylvanian units overlie the Mississippian units. The older of the two is the Pottsville Formation, and the younger is the Allegheny Formation. These formations are lithologically similar, each is a brownish, coarse-grained sandstone with interbedding of limestone, shale and coal. Locally the units may be conglomeratic. The Pennsylvanian rocks occur as land surface throughout most of the basin. A thin layer of alluvium overlays Pennsylvanian units in the Tug Fork Valley. The alluvium, of Quaternary age, is composed of fine-grained sand, silt, and clay. Generally, it is less than 10 feet thick. Of the units present, the Pennsylvanian rocks have the greatest potential for the development of ground-water supplies.

The sedimentary rocks in the basin have been subjected to tectonic forces which resulted in at least two major fault systems traversing the basin. A northern extension of Pine Mountain Thrust fault crosses the headwaters of the basin in McDowell County, West Virginia (Fig. 19). An extension of the Kentucky River fault crosses the basin between Williamson and Kermit. This fault is associated with the Irvine-Paint Creek uplift in Lawrence and Johnson Counties, Kentucky. Normally, many small lateral and cross faults are associated with these major fault systems. Therefore, the rocks in the vicinity of the fault systems are usually highly fractured and considerably more permeable than rocks at some distance from the faulting.

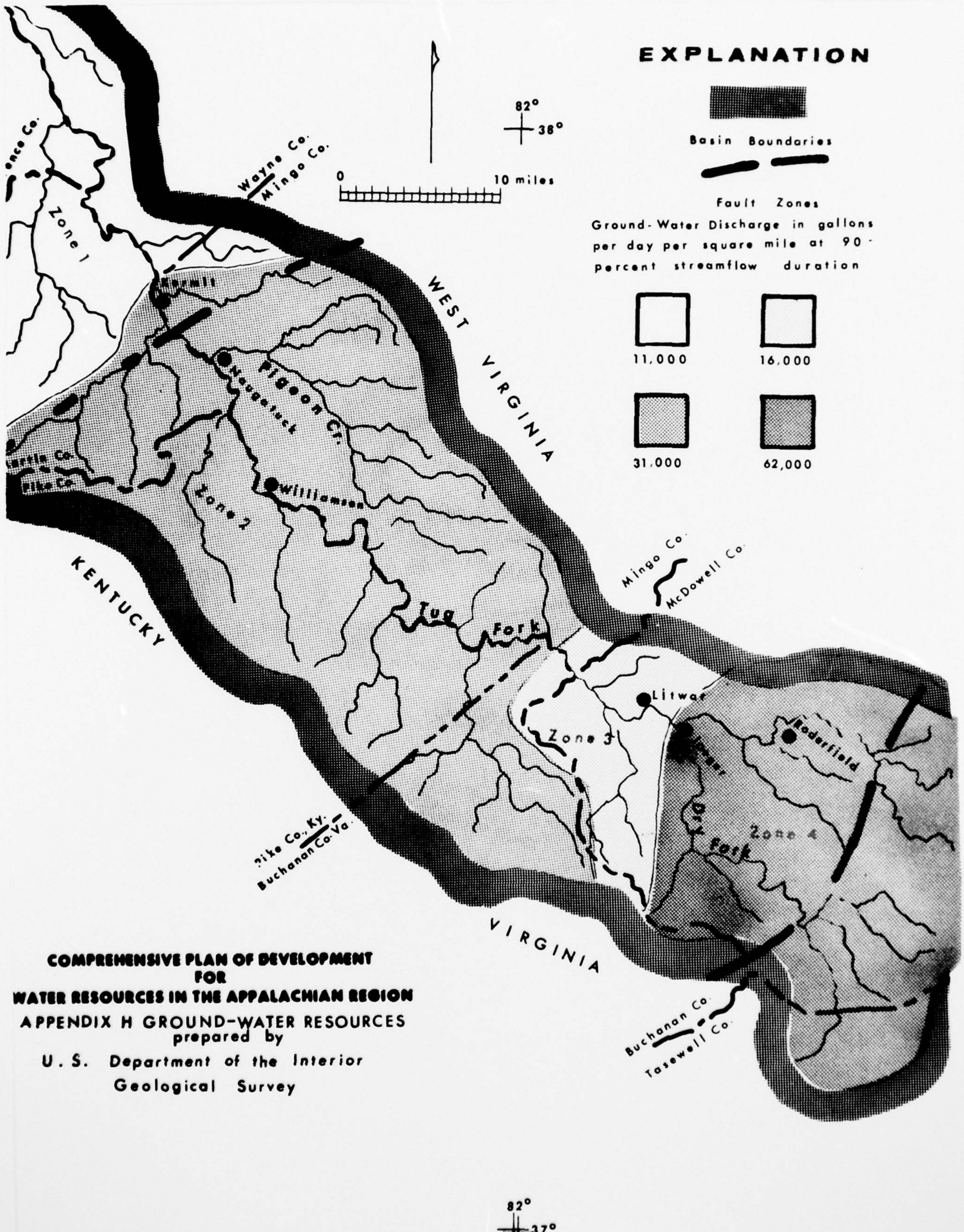

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Figure 19. The Lower Knox Area

The relationship of ground water to surface water in Tug Fork Basin is such that the two can hardly be described separately. During periods of low flow in the streams, ground water drains to the streams forming a part of the flow. When the flow of the streams in this basin declines to the point where it is exceeded about 90 percent of the time, it may reasonably be assumed that all of the flow in the streams is ground-water base flow. Thus, the amount of streamflow at 90 percent duration may be used as an indication of the available ground water. Based upon data from stream-gaging stations where duration curves have been developed, the basin was divided into four ground-water availability zones (Fig. 19).

Ground-water Zone 1 and 3 are in areas relatively unaffected by the faults traversing the basin. They have the lowest available ground water in gpd per square mile. Zone 1 averages about 11,000 gpd per square mile and Zone 3 averages about 16,000 gpd per square mile. The rocks in Zones 2 and 4 are more permeable as a result of faults that cross the basin in these two zones. This is shown by the available ground water quantities indicated by low flow stream measurements. The available ground water in Zone 2 averages about 30,000 gpd per square mile and Zone 4 averages about 62,000 gpd per square mile.

Stream flow at low stage indicates the available ground water in a basin because at low flow the water is derived from ground-water sources. Therefore, the chemical quality of stream water is directly related to the chemical quality of the ground water.

Ground water in consolidated rocks of Tug Fork Basin is typically a high sodium bicarbonate type. The pH of the water is generally 7 or above, the bicarbonate content ranges from about 200 to about 400 ppm. Generally the hardness of water from the consolidated rocks is greater than 120 ppm. The chloride content of water from depths greater than about 100 feet exceeds 250 ppm in Zone 1. In Zones 2 and 4 it is usually more than 300 feet to water which contains chloride in excess of 250 ppm.

Table 1 indicated the changes in quality of water in the Tug Fork at Kermit as a result of changes in amount of streamflow. The table also gives analyses of water from various sub-basins in Tug Fork basin during a period when the streamflow was low and the water was derived primarily from ground-water sources. In all the sub-basins investigated, except Pigeon Creek which is reportedly polluted by acid mine drainage, the quality of the water was typically that of ground water. The pH, bicarbonates, and chlorides were high and the iron content was low. The analyses of water from Tug Fork, Kermit, show the changes that occur in quality of water as the streamflow is derived more from surface runoff and less from ground-water sources. The pH, bicarbonate, and chlorides decreases with increased runoff flow.

The yield of wells varies in the basin according to the zones in Figure 19. Wells in Zone 1 should be about 100 feet deep and will yield about 25 to 50 gpm. Below depths of about 100 feet wells in this zone may yield water containing more than 250 ppm of chloride. Wells in Zone 2 may be 200 to 300 feet deep and will produce 100 to 200 gpm. Wells in Zone 3 may be 200 to 300 feet deep and will produce 40 to 70 gpm. Wells in Zone 4 may be 200 to 300 feet deep and will produce 200 to 300 gpm. It is assumed in the above discussion that the wells will be constructed in the valleys and that the wells in Zones 2 and 4 will be in the general vicinity of the fault systems.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water in each zone, per thousand gallons for raw water delivered at the well head are listed below. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. The cost of water per thousand gallons for each zone is:

Zone 1 - $0.11
Zone 2 - $0.07
Zone 3 - $0.09
Zone 4 - $0.04

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TABLE I

CHEMICAL CONSTITUENTS OF SURFACE WATER, TUG FORK BASIN

Location	Date	(cfs)#	Fe*	Na*	HCO_3*	SO_4*	Cl*	pH
Tug Fk., Roderfield	10/5/60		.21		376	224	9.0	7.9
Dry Fk., Iaeger	10/5/60		.10		361	152	18	8.1
Tug Kr., Litwar	10/5/60	49	.17	142	386	198	14	7.6
Pigeon Cr., Naugatuck	10/4/60		6.6		0	810	15	4.1
Tug Fk., Kermit	10/4/60	85	.22	100	216	253	18	7.5
	12/5/60	179	.08	53	112	160	12	7.4
	1/10/61	310	.29	.26	58	110	7.0	6.7
	2/13/61	3730	1.5	8.6	22	57	4.0	6.2
	4/19/61	2850	.37	13	42	74	3.5	6.9
	5/22/61	1000	.14	39	106	162	5.0	7.1
	9/13/61	141	.09	75	168	215	10	7.8

* Constituents reported in parts per million
\# Instantaneous discharge in cubic feet per second

Analyzed by the U. S. Geological Survey

SALYERSVILLE AREA

Royalton Reservoir is proposed as a multipurpose reservoir which among other purposes, will furnish additional water supply for Salyersville, Kentucky. Salyersville is in the Kanawha section of the Appalachian Plateaus province (Fenneman, 1946). The town lies at an intersection of valleys in the Licking River Basin near the confluence of Burning Fork and Licking River. Land-surface elevations near Salyersville range from about 850 feet above msl (mean sea level) in the valleys to about 1200 feet above msl on the ridges. The town is underlain by more than 1000 feet of rocks of sedimentary origin. The Saylersville municipal water supply is derived from ground water that occurs in the sedimentary rocks.

The deepest water wells in the area bottom in rocks of Pennsylvanian age at about 660 feet below land surface in the valleys (Price, 1962a and 1962b). The rocks of Pennsylvanian age include two formations in this area. The older of these, the Lee Formation, extends from more than 660 feet to about 300 feet below land surface. It is overlain by the Breathitt Formation which extends to and forms land surface in most of the area. Locally, the Breathitt Formation is overlain by Quaternary alluvium deposits in the stream valleys.

The Lee Formation is a massive, crossbedded sandstone containing a few, thin, interbedded shale layers. Ground water occurs in the intergranular pore space of the sandstone units and in fractures of the sandstones and shales. The most productive wells tap fracture zones in the sandstone units.

The Breathitt Formation is also a massive sandstone containing interbedded shale layers. The shale to sandstone ratio is much higher in the Breathitt Formation than in the Lee Formation. In addition to containing more shale, the Breathitt Formation also contains coal beds and limestone beds. Tests indicate (Price, 1962a) that the porosity of unfractured samples from the Lee Formation is nearly the same as the Breathitt Formation and that the permeability of the Lee Formation is greater than that of the Breathitt Formation. The most productive wells in the Breathitt Formation, also, are those which tap fracture zones.

The alluvium deposits in the valley at Salyersville are sand, silt, and clay. The deposits are less than 50 feet thick and would average less than 0.3 mile wide in this area. Generally, these deposits will furnish sufficient water to wells for individual domestic supplies but, because they are poorly sorted and limited in thickness and areal extent, they would not furnish sufficient water for municipal or industrial wells.

Wells tapping the Breathitt and Lee Formations derive water principally from fracture zones in the rocks. The highest yields are reported in stream valleys where fractures are more numerous (Dove, 1967). Mr. H. T. Hopkins, of the Geological Survey District Office in Louisville, Kentucky, reports[1] that recent tests of a well at Salyersville indicate a specific capacity of about 1 gallon per minute per foot of drawdown. He reports that the present treatment plant has a capacity of about 200,000 gpd and the 1958 consumption averaged about 49,000 gallons per day. Thus, the plant has a capacity of about four times that use and the well, pumped at 150 gpm, will supply about four times that use. The raw water had a total hardness of 14 ppm and contained 0.04 ppm of iron and 192 ppm of chlorides in 1958 and 198 ppm of chlorides in 1963. The water is treated by aeration and chlorination.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be \$0.06 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at \$0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at \$0.06 per thousand gallons) is calculated at about 14 thousand gpd per square mile.

1. The present system will supply more than twice the 1958 average daily consumption at less than \$0.06 per 1000 gallons of raw water.

2. The quality of the raw water is generally acceptable except for bicarbonate and chloride content. The chloride content of water from the present well was below the maximum (250 ppm) recommended by the U. S. Public Health Service after 32 years of use. The bicarbonate content was about 400 ppm in 1963 and imparts a slight taste to the water.

3. It is not likely that more than two additional wells, of approximately the same quality and yield, could be constructed in the space available at the intersection of the river valley and the Kentucky River Fault, about two miles downstream from Salyersville. Thus, the projected water requirement of about 4 mgd could not be met from ground-water sources.

1. Personal communication

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KINGDOM COME RESERVOIR AREA

Kingdom Come Reservoir is proposed as a multipurpose reservoir which, among other purposes, could furnish additional water supply for Hazard, Kentucky. The following deals primarily with ground-water occurrence and availability at Hazard. Hazard is in the Kanawha section of the Appalachian Plateaus province (Fenneman, 1946). The town is on the North Fork of the Kentucky River. Land surface elevations near Hazard range from about 900 feet above msl in the valleys to about 1700 feet above msl on the ridges. The area near Hazard is underlain by more than a thousand feet of rock of sedimentary origin. The Hazard municipal water supply is derived from surface water of the North Fork of the Kentucky River.

The deepest water wells near Hazard bottom in rocks of Pennsylvanian age at about 150 feet below land surface in the valleys (Price, 1962a and 1962b). The rocks of Pennsylvanian age extend to depths of more than a thousand feet in this area (Price, 1962a). The only Pennsylvanian Formation tapped by water wells is the Breathitt Formation. The Breathitt Formation extends from about 600 feet below land surface to land surface. The resistant sandstone units of the Breathitt Formation form the ridges in this area. Wells tapping the Breathitt Formation derive water primarily from the fracture zones in the rock.

Alluvium deposits of Quaternary age occur locally, over the Breathitt Formation, in stream valleys. The alluvium deposits are thin, poorly sorted clay and sand layers that yield limited quantities of water to wells. Generally, the wells in alluvium deposits will furnish sufficient supplies for individual domestic use but wells in the alluvium would not furnish adequate supplies for industrial or municipal use.

Wells tapping the Breathitt Formation derive water principally from fracture zones in the rocks. Therefore, wells in the valleys where fractures are more numerous and are saturated will generally have the highest yields (Dove, 1967). The highest yields are reported as about 70 gpm. The average yield would probably be 30 to 40 gpm for wells about 150 feet deep. The present consumption for Hazard requires a supply of about 100 gpm for 12 hour operations. To produce such a supply from ground-water sources would require more than 30 wells. The following is based upon a well field of 30 wells operating 12 hours a day.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.12 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at $3\frac{1}{4}$ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.12 per thousand gallons) is calculated at about 16 thousand gpd per square mile.

The necessity for developing a large number of wells and the resulting high cost per 1000 gallons of water produced indicates that the present source, the river, is the most economical for a municipal supply at Hazard.

Ground water is available up to several hundred gpm to local well fields where some special characteristics of the water, such as a more constant temperature, is desirable for industrial use.

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CARTER COUNTY AREA

The Carter County area is in the northeastern part of Tennessee and includes parts of two physiographic provinces. Most of the eastern and central parts of the county are in the Blue Ridge province and the western part is in the Valley and Ridge province. The area is underlain by rocks that range from Precambrian through Ordovician in age. Major faults trend northeast-southwest through the county and extensive cross faulting has occurred at nearly right angles to the major faults. Ground water occurs mainly in the fractures in basement rocks and occurs extensively in solution channels that developed along fracture patterns in the limestone and dolomite units of basement rock.

The oldest rocks that outcrop in the area are of Precambrian age. These rocks occur in the southeastern part of the area and are principally granite although they contain units of garnet gneiss, and hornblende gneiss. Ground water in these rocks occurs in the fracture zones. Wells tapping the Precambrian rocks will yield as much as 55 gpm although their yield generally does not exceed about 6 gpm.

Rocks of Cambrian age outcrop in a band trending northeast through the central part of the county and also in the northern part of the county. The Cambrian rocks are interbedded sandstone and shale. The sandstone is both quartzite and feldspathic sandstone. In the Cambrian rocks, ground water occurs mainly in fracture zones and to a lesser extent in the intergranular pore space in the sandstone units. Wells tapping Cambrian rocks will yield as much as 500 gpm although such large yields are rare and depend upon the wells tapping major fracture areas. Generally, a well tapping Cambrian rock will not yield more than about 12 gpm unless it is located near the intersection of major faults and cross faults.

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Ordovician rocks outcrop in the western and southwestern part of the county. The Ordovician rocks are mainly limestone and dolomite with minor interbedding of silt or chert units. The Ordovician rocks are fractured from both jointing and faulting. Where ground water has circulated through [illegible] fractures, the openings have been enlarged by solution [illegible] dolomite and limestone and the solution channels are highly productive sources for ground-water supply. Wells tapping solution channels near Elizabethtown produce more than 2000 gpm each (Fig. 20). The water from these wells is apparently a combination of ground water from storage and infiltration from the Watauga River.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water in the high yield zone (Fig. 20) would be $0.01 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at $3\frac{1}{4}$ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.01 per thousand gallons) is calculated at about 400 thousand gpd per square mile.

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DeBuchananne, G. D., and Richardson, R. M. 1956, Ground-water resources of East Tennessee: Tennessee Dept. Conser., Div. Geology Bull. 58, pt. 1, 393 p.

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CLINCHFIELD RESERVOIR AREA

by

Carlton T. Sumsion[1]

The upper Broad River basin is largely within North Carolina. The basin includes the Broad River and its tributaries headward from about 2 miles southwest of Cliffside, North Carolina. The drainage basin includes 653 square miles within the Blue Ridge and Piedmont provinces of the Appalachian Highlands (Fenneman, 1946).

Land surface within the drainage basin ranges from about 650 feet at the lower end to 4,412 feet above msl on the northwestern border of the basin. The terrain is irregular, with steep valleys in the headwaters areas and less extreme relief at the lower, southeastern drainage. The entire basin is underlain by crystalline rocks of the Blue Ridge-Piedmont metamorphic complex.

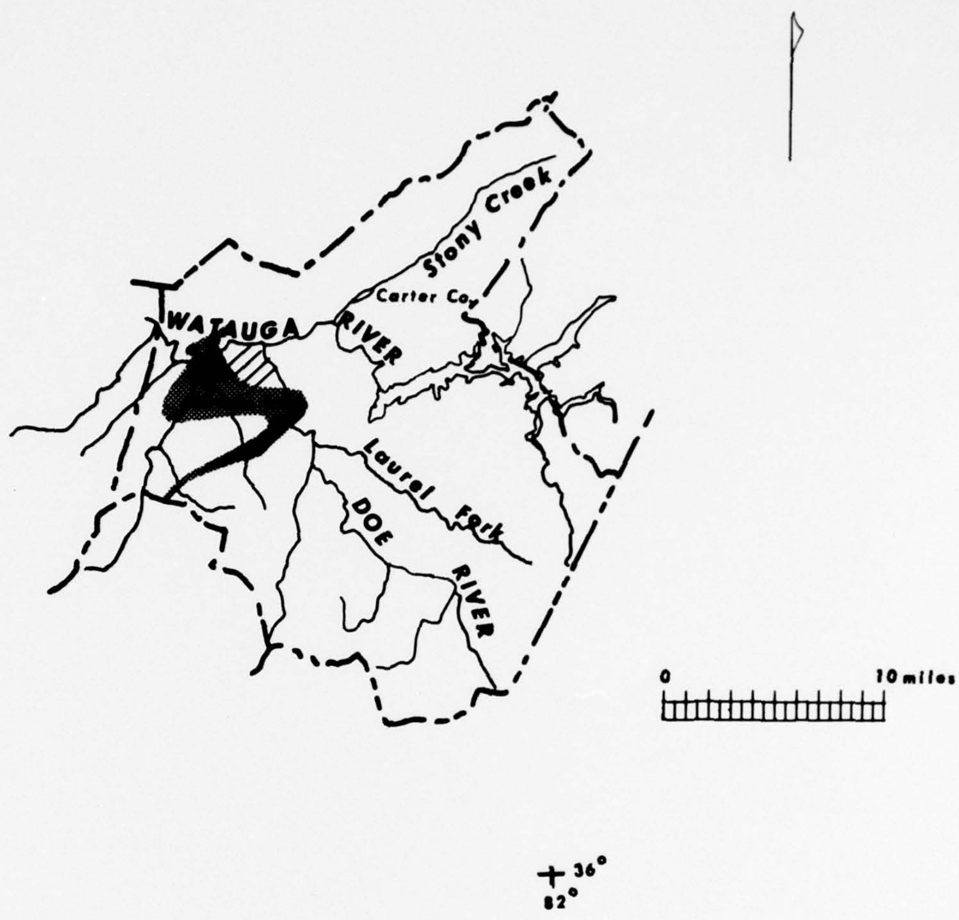
Geology and ground water in this basin are described as part of an investigation by LeGrand and Mundorff (1952).

The crystalline rocks underlying the upper Broad River basin are chiefly granitic gneiss and mica gneiss (Fig. 21). These rock types are not homogeneous, but include a wide compositional range from schists to quartzites. Of probably Paleozoic (?) age, these rocks of igneous and sedimentary origins have been compressed into tight, northeast-trending, asymmetrical folds by regional stresses in the earth's crust. Erosion has beveled the folds, reducing the topography to its present configuration, and weathering of the metamorphosed rocks has produced a regolith of surficial clays which may be nearly a hundred feet thick in the lower valleys.

Ground water occurs in the weathered surficial clays, in valley alluvium, and within fractures of the underlying crystalline rocks. Fracture systems, chiefly joints, are well developed and have produced avenues more susceptible to erosion for evolving stream courses, hence the stream patterns are predominately rectangular. These patterns are most conspicuous in the Blue Ridge section of the drainage basin.

The surficial clays yield ground water to dug or bored wells of very low specific capacities. Water-bearing fractures in crystalline rocks yield ground water of excellent quality to wells of low and moderate specific capacities. Wells having the best yields produce an average of 30 gpm from depths of 100 to 200 feet. These wells are drilled in low, flat areas within linear valleys. To produce one mgd, about 24 wells, 200 feet deep, would be required.

1. Geologist, U. S. Geological Survey, Raleigh, North Carolina



EXPLANATION

Yield of Wells more than 2000 gallons per minute

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Figure 20. The Carter County Area

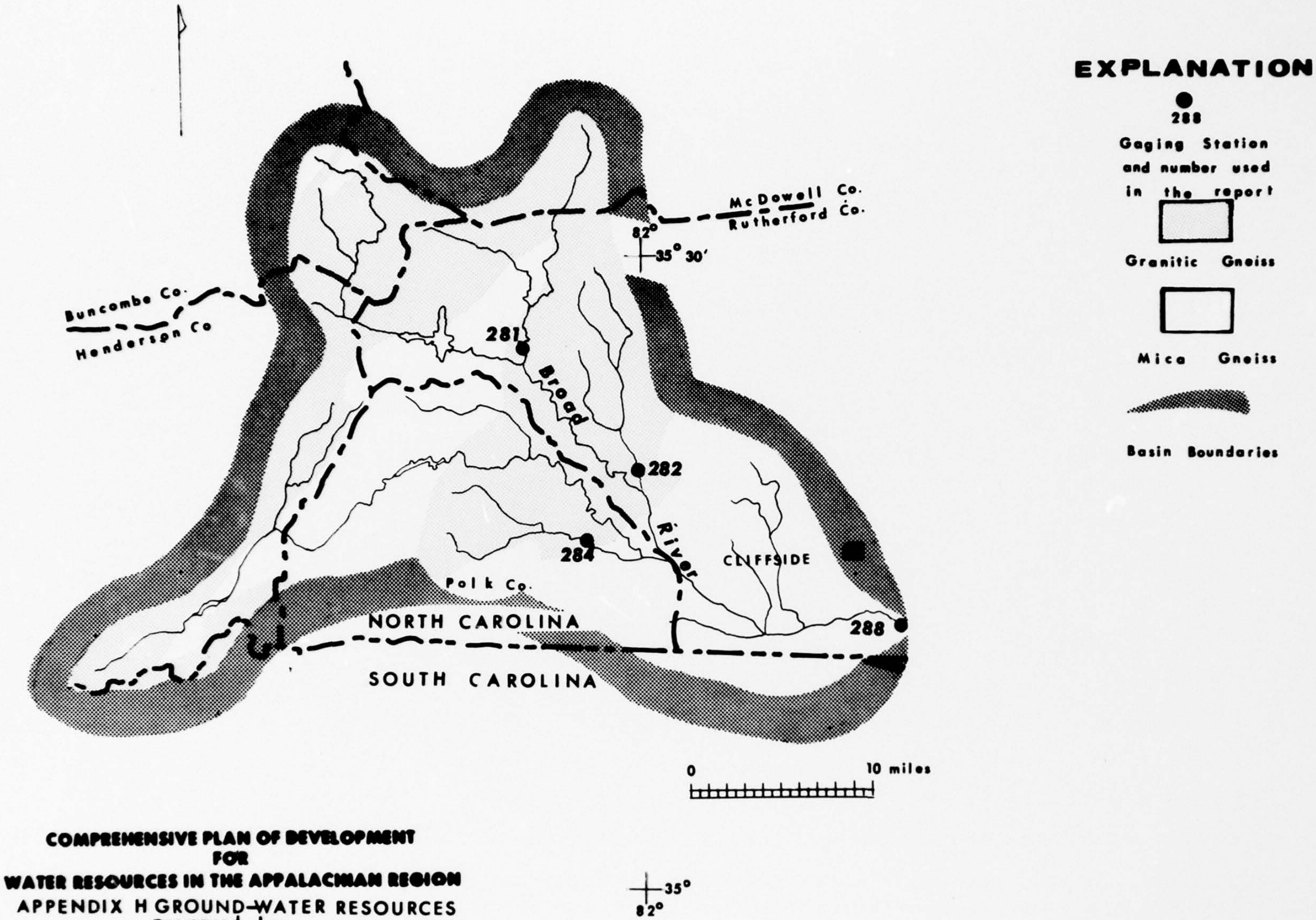

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Figure 21. The Clinchfield Area

Ground water contributes to the flow of streams in the basin. It may be measured as the sustained or fair-weather flow (also known as base flow) which constitutes the flow of the stream after surface runoff has ceased. Base runoff (or base flow) may be expressed as the streamflow exceeded 90 percent of the time, although this is not entirely base runoff. Base runoff is relatively uniform, averaging about 0.440 mgd per square mile, in the upper Broad River basin. Base runoff indicated the available ground water from the weathered surficial overburden and valley alluvium as well as that from fractures in crystalline rocks. During August and September the chemical characteristics of streamflow closely resemble those of ground water in the basin.

The chemical quality of ground water from drilled wells in the upper Broad River basin is excellent. It is a typical calcium, magnesium, sodium, bicarbonate water common to source areas of quartz-biotite gneiss, or a type-I ground water as described by Marsh and Laney (1966, p. 61). The hardness of this ground water is usually less than 50 ppm, iron is less than 0.1 ppm, pH is slightly less than 7, and total dissolved solids seldom exceed 50 ppm.

The construction of a well field capable of producing 1 mgd would require drilling and equipping about 24 wells yielding about 30 gpm each. The cost of construction, exclusive of exploration and testing and real estate cost, would be about $31,000.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.11 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.11 per thousand gallons) is calculated at about 55 thousand gpd per square mile.

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DALTON AREA

Dalton reservoir site is about 4 miles southeast of Dalton, Whitfield County, Georgia. The proposed reservoir would impound the Conasauga River and would, among other services, supply water for both Dalton and industrial development northwest of Dalton. The area of study, west of Conasauga River, is within the Valley and Ridge province. This area is underlain by well indurated rocks that range from Cambrian through Ordovician in age.

The rocks in the area of study are highly folded. The strike of the outcrops is generally northeast-southwest and structure is generally a series of synclines with two major fault zones traversing the area parallel to the outcrops. The oldest rocks exposed are of Cambrian age. Two formations of this age outcrop in the area. The older, Rome Formation, is generally interbedded siltstone, shale and sandstone. The unit is primarily a calcareous shale containing thin stringers of very fine-grained sandstone. In the area of study this unit is not a good aquifer. The other Cambrian unit is the Conasauga Formation. The Conasauga Formation is primarily a limestone unit with interbedded siltstone and shale. This formation is generally a productive aquifer where fracture zones in the limestone have been enlarged by solution. The Conasauga Formation is included in the zones indicated on Figure 22 as having more than 50 gpm ground-water potential for well yield.

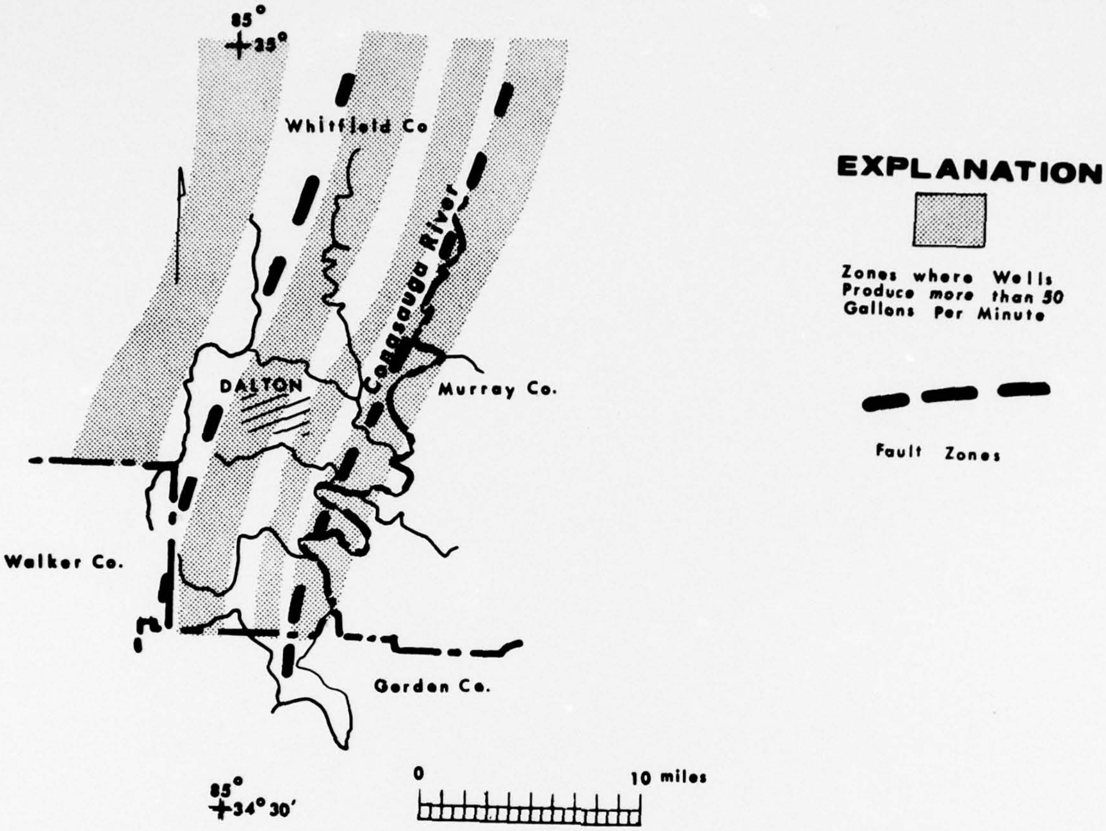

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Figure 22. The Dalton Area

The Knox Group of the Ordovician and Cambrian Systems outcrops between the exposures of the Conasauga Formation in the area of study. Units of the Knox Group are composed of dolomite and dolomitic limestone. Ground water occurs in abundance in fracture zones in this group where solution has enlarged the fractures. The Knox Group is also included in the zone having more than 50 gpm potential well yield in Figure 22.

Wells developed for maximum yield in the area average about 125 feet in depth below land surface. A well field capable of producing 1 mgd would cost about $24,000. The water from such a well field would probably require treatment for excessive concentrations of dissolved iron and hardness. The iron content of water will range from about 0.01 ppm to about 2.0 ppm. The chloride content of water in the area is less than 15 ppm. The hardness of water ranges from about 85 ppm to more than 400 ppm.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be $0.08 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at $0.08 per thousand gallons) is calculated at about 45 thousand gpd per square mile.

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NORTHPORT RESERVOIR AREA

Northport reservoir site is in the central part of Tuscaloosa County, Alabama. The site is approximately 6 miles northeast of the cities of Tuscaloosa and Northport and the proposed reservoir is planned to provide, among other services, water supply for these cities. The proposed reservoir will impound water in the North River, a tributary of Black Warrior River.

The drainage basin of North River is almost entirely within the Appalachian Plateaus province (Fenneman, 1946). The cities of Tuscaloosa and Northport are in the Coastal Plain province. The Fall Line, dividing the Coastal Plain from the Appalachian Plateaus, is between the city of Tuscaloosa and the confluence of the North and Black Warrior Rivers. The entire area of study is underlain by sedimentary rocks that range from Pennsylvanian to Recent in age.

The oldest rocks that outcrop in the area are units of the Pottsville Formation of Pennsylvanian age. These rocks cropout in the eastern part of the area and dip under younger rocks to the south and west. The Pottsville Formation is composed of well-indurated sandstone interbedded with shale and conglomerate. Coal beds of economic value are also interbedded with the other lithic units of the Pottsville Formation.

The Pottsville Formation is overlain by rocks of the Coker Formation of Cretaceous age. The rocks of the Coker Formation are unconsolidated, lenticular beds of sand, clay and gravel. The basal gravel bed is reported to be highly permeable. Unconsolidated sediments of both terrace deposits and valley alluvium overlie the Coker and Pottsville Formations. The terrace and alluvium deposits are sand, clay and gravel of Quaternary age. In general, rocks older than Cretaceous age are well-indurated and rocks of Cretaceous age and younger are unconsolidated.

Ground water occurs under both artesian and non-artesian (water-table) conditions in the area of study. Water in the Pottsville and Coker Formations, generally, is under artesian conditions and water in the Quaternary deposits is under nonartesian or, locally, semiartesian conditions. The most abundant supplies of ground water from the Pottsville Formation occur in fracture zones in the rocks and, to a lesser extent, in the intergranular pore space of the rocks. In the Coker Formation and in the Quaternary deposits the ground water occurs in the intergranular pore space of the sand and gravel beds.

Wells drilled in the Pottsville Formation northeast of the Fall Line yield from about 6 to 50 gpm. The water has a chloride content ranging from 2 to 10 ppm and the hardness ranges from about 80 to 150 ppm. These wells are between 150 and 250 feet in depth below land surface. It is unlikely that wells capable of supplying the quantity of water required for extensive industrial or municipal use could be developed economically from the Pottsville Formation in the area northeast of the Fall Line (Fig. 23).

Wells tapping the Coker Formation southeast of the Fall Line will produce between 20 and 200 gpm. The wells reported were not constructed for municipal or industrial use and, therefore, were not designed, constructed and developed for the maximum yield. Pumping tests indicate that wells in the Coker Formation about 6 miles southwest of the city of Tuscaloosa will produce more than 200 gpm each, if designed for the maximum yield. The water quality would be acceptable for municipal use without extensive treatment. The hardness of water is about 35 ppm and the chloride content of the water is about 60 ppm.

Wells tapping the Quaternary deposits in the Black Warrior River valley about 6 miles southwest of Tuscaloosa have the highest reported yields in the area of study. One well was tested at 1500 gpm for more than 24 hours. Other wells tested indicated yields in excess of 100 gpm. The quality of water from the Quaternary deposits is generally good except for objectionable concentrations of dissolved iron; the water would generally require treatment for iron removal before being acceptable for municipal use.

Ground water may be developed from well fields about 6 miles southwest of Tuscaloosa for municipal or industrial supply from multiple-screened, gravel-packed wells tapping each water-bearing zone in the Quarternary and in the Coker Formations.

On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water would be \$0.04 per thousand gallons for raw water delivered at the well head. Some of the basic assumptions were; that the sustained yield of the well field would be 1 mgd with power costs at \$0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. In this area the optimum development (at \$0.04 per thousand gallons) is calculated at more than 500 thousand gpd per square mile.

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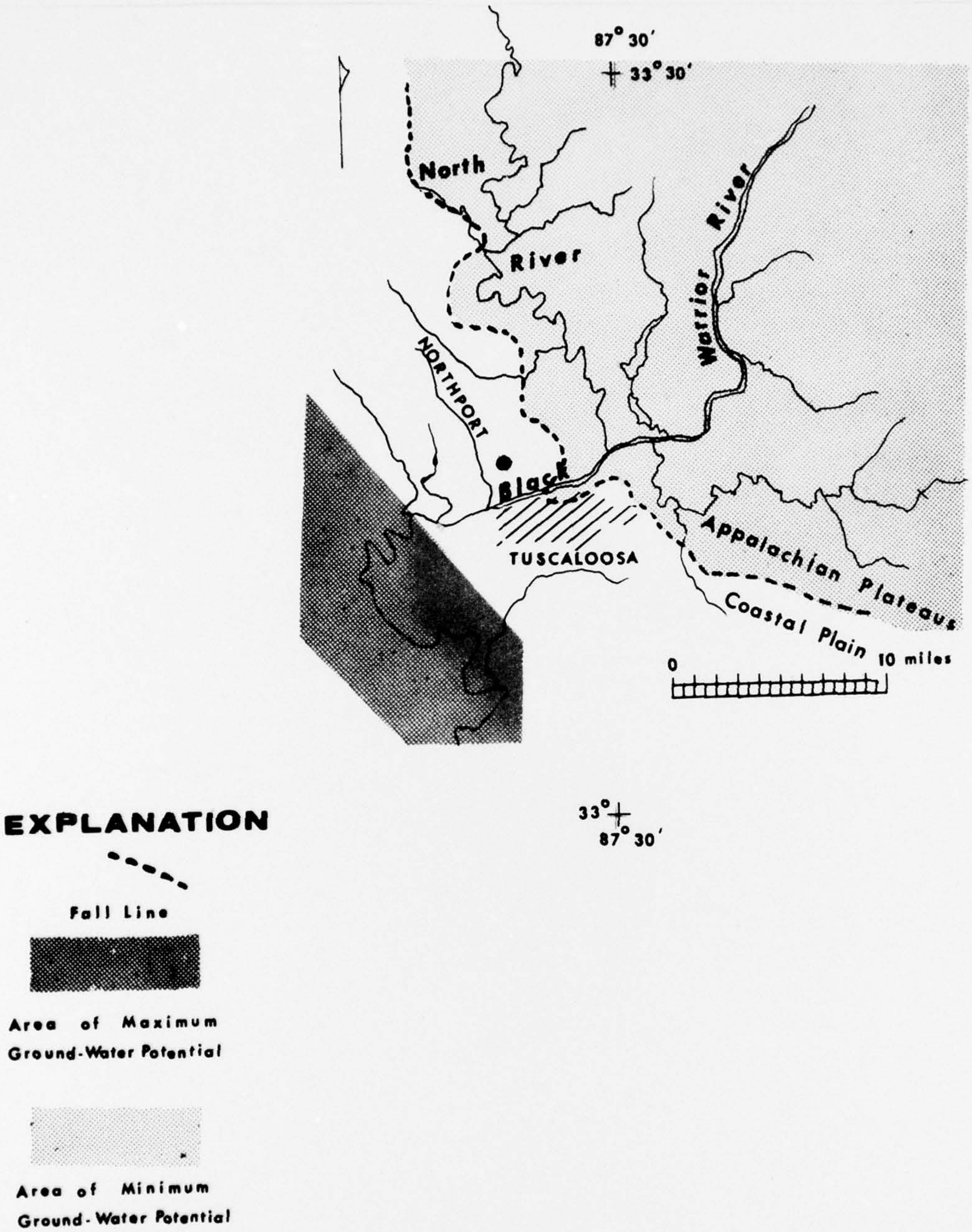
NAVIGATION PROJECTS

Coosa River and Tombigbee River

The Coosa River Navigation project extends along the Coosa River from Floyd County, Georgia to Elmore County, Alabama, in the southern part of the Region. Also in the southern part of the Region, the Tombigbee River Navigation project extends along the Tombigbee River from Tishomingo County, Mississippi to Pickens County, Alabama. Although a navigation project is not usually concerned with water supply, abundant water supply along a main transportation route may increase the potential of the area for industrial development. Thus, the abundance or lack of available water supply can increase or decrease the ultimate economic value of a navigation project. This summary will list the estimated cost and availability of ground water as a source of water supply in the counties adjacent to the projects but will not attempt to evaluate the effects of the navigation projects upon the ground-water resources. Such an evaluation would require rather lengthy, detailed hydrologic studies at each point of construction along each project area. In general, the rise in stream level and the lowflow augmentation normally associated with completed navigation projects increases the ground-water potential near the stream. This is particularly true when extensively developed ground-water supplies depend upon stream-to-aquifer infiltration for recharge, as may well occur in all of the listed counties.



COMPREHENSIVE PLAN OF DEVELOPMENT
FOR
WATER RESOURCES IN THE APPALACHIAN REGION

APPENDIX H GROUND-WATER RESOURCES
prepared by
U. S. Department of the Interior
Geological Survey

Figure 23. The Northport Area

The basis for estimating the cost and availability of ground water has been described in Part I. On the basis of the assumptions explained and delimited in Part I of this report, the cost of producing ground water per thousand gallons for raw water delivered at the well head is shown, for each county along the navigation projects, in Table II. Some of the basic assumptions were: that the sustained yield of the well field would be 1 mgd with power costs at $0.025 per KWH; and that construction costs would be depreciated over a 25-year period with interest at 3¼ percent. Not included were the costs of real estate or of exploratory drilling and testing. These estimates stop short of actual design. For this purpose, competent professional assistance should be obtained. The table is designed for use in preliminary planning to indicate where ground-water supplies may be economically developed, in association with the navigation projects, to stimulate the local economy. The optimum development for ground water has been omitted from the table since, in most counties, the availability of ground water along the streams is dependent partially upon sustained low-flow, which will be altered by the projects.

TABLE II

YIELD OF WELLS AND COST OF GROUND WATER ALONG NAVIGATION PROJECTS

County	State	Yield of Wells[1] (gpm)	Cost of Ground Water (dollars per thousand gallons)[2]
	Coosa River Navigation Project		
Floyd	Georgia	75	0.13
Cherokee	Alabama	350	0.04
Etowah	Alabama	300	0.05
Calhoun	Alabama	770	0.02
St. Clair	Alabama	250	0.08
Talladega	Alabama	270	0.09
Shelby	Alabama	150	0.13
Coosa	Alabama	70	0.31
Chilton	Alabama	85	0.26
Elmore	Alabama	80	0.28
	Tombigbee River Navigation Project		
Tishomingo	Mississippi	112	0.06
Prentiss	Mississippi	240	0.08
Itawamba	Mississippi	200	0.05
Monroe	Mississippi	1100	0.01
Clay	Mississippi	698	0.03
Lowndes	Mississippi	516	0.05
Pickens	Alabama	275	0.12

1/ Yield is average of existing municipal and industrial wells (see list of selected references for Parts I and II for sources of data)

2/ Cost per thousand gallons as delimited in text

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